CINEMATOGRAPHIC ANNUAL

1930

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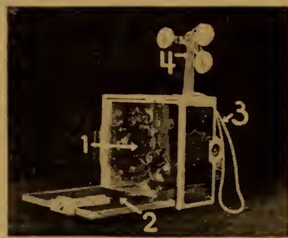
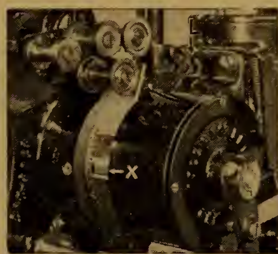


Speed movement of silent B. & H. camera equipped for sound work. 1—Check-pawl super-speed movement. 2—Felt lining of camera door. 3—Endless fabric belt. 4—Silent belt tightener.



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CINEMATOGRAPHIC ANNUAL

1930

Volume One

Edited by

HAL HALL, Ph.B.

Editor, *The American Cinematographer*

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PREFACE

FOR many years the feeling has existed among the technical men of the motion picture industry that out of the industry should come an annual publication of a highly technical nature; a book that would be almost in the nature of a text-book; a book that would be of value to everyone connected in any way with motion pictures.

The governing board of the American Society of Cinematographers long discussed the publication of such a volume, and a year ago decided that this organization would do it. This volume is the result, and it is respectfully dedicated to that group of tireless workers whose endeavors and vision have made the motion picture the world's greatest form of entertainment, and who have developed it from a few flickering shadows to a magnificent form of art.

We hope this book will meet with your approval. In this, the first volume, we have perhaps left out important features. That is but natural. However, from year to year we hope to add improvements which will eventually make this Cinematographic Annual what we wish it to be—one of the most valuable publications pertaining to motion pictures.—*Hal Hall, Editor.*

Hollywood, California,

April 1, 1930.


IDEALS and HARD WORK
. . . together with technical knowledge and constructive thinking have been most successfully combined to produce and perfect INKIES. For that matter these vital elements must be used in developing any product which will endure. The same ideals and the same hard work, the same painstaking, careful thinking and the same skilled craftsmanship that produced INKIES are constantly searching for new fields to conquer in the motion picture industry. . . . That is why DIMMER BANKS, CAMERA DOLLIES, and MICROPHONE BOOMS, each involving new perfections and new standards of craftsmanship, have been added to the Mole-Richardson line. That is why "M-R" Headquarters has earned the name of . . . "Improvement" Headquarters . . . and it is the friendly cooperation of the industry which is keeping it that way. . . . . . .
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APPRECIATION

THE preparation of a volume such as this is a task which cannot be successfully completed without the co-operation of the best technical minds of the industry. We have had this co-operation and wish to take this opportunity of expressing our deep appreciation to the following men and organizations:

Thomas A. Edison, George Eastman, Dr. W. B. Rayton, Emery Huse, the Academy of Motion Picture Arts and Sciences, Western Electric Company, R. G. Farnham, National Lamp Works, Electrical Research Products, Inc., R. C. A. Photophone, Fox-Case Movietone Corporation, Bell and Howell Company, The Fearless Camera Company, The Mitchell Camera Company, Louis Physioc, Slavko Vorkapich, H. W. Moyse, D. R. White, J. I. Crabtree, G. E. Matthews, J. F. Ross, Max Factor, William Cameron Menzies, the Society of Motion Picture Engineers, the Eastman Kodak Company, the Dupont Pathe Film Manufacturing Corporation, Pathex, Inc., Victor Animatograph Company, Houghton-Butcher, Ltd., and all others who have assisted in any way with the work.

Cable Address "Edison, New York"

From the Laboratory of Thomas A. Edison, Orange, N.J.

February
thirteenth
1930

American Society of Cinematographers, Inc.,
Suite 1222 Guaranty Building,
Hollywood, Calif.

Gentlemen:

Although I greatly appreciate the compliment of being invited to write a foreword to your forthcoming book, to be called the "Cinematographic Annual," I shall have to ask you to kindly excuse me from making a favorable response. I receive numerous requests to write articles, statements, forewords, etc., but never attempt to comply for the reason that writing is entirely out of my line and I would not care to undertake it.

However, it seems to me, after considering the object and scope of a book as described in the letter of your President, Mr. John F. Seitz, that the "Cinematographic Annual" will find a most useful place in the literature on the subject, and I beg to express the hope that the expectations of its sponsors may be fully realized.

Yours very truly

Thos A Edison

Ediphoned-C

John F. Seitz

INTRODUCTION

*John Seitz**

THE motion picture of today is the greatest medium of expression the world has ever known. Its possibilities are as limitless as the written word. But few there are who even faintly realize its destiny; the power it will exert in influencing mankind before it will be supplanted (if ever) by a more expressive medium.

All of our present knowledge had its beginning in the fixation in some form, such as writing, drawing or sculpture, of the thoughts and emotions of our predecessors on this earth. Until our emotions and thoughts are fixed in definite form they cannot live after us or be transmitted to others. It can be stated therefore, that the written word, the most abstract, flexible and limitless medium of thought transmission, has been the basis of practically all of our present knowledge and progress.

It is to the art of writing, alone, with its limitless power of expression, that the talking picture can be successfully compared. It is useless to compare the motion picture to painting, sculpture, music, the drama and other arts because of their obvious limitations. Each of these arts, supreme in its particular realm, never attempts to go beyond certain well-defined limits. The color of Titian and Veronese, the form of Michelangelo and Phidias, the symphonies of Beethoven and Brahms, are beyond word description. No writer, however great, could give an idea the same form or substance in words that the masters of these arts imparted to canvas, stone and music.

All ideas of the earth, its life, the thoughts and emotions of its people, can be expressed in more or less satisfactory manner in words; certain ideas of nature and life can be expressed through painting, sculpture, music and other arts much more perfectly and completely than in writing. But, whereas these arts express only those phases of life which lie within their particular provinces, the whole of nature with all its complex life, lies within the province of the pen.

As the fine arts are superior to words in completeness of expression, so will the motion picture of the future be superior to writing in expressing every concrete form and phase of human endeavor. As a medium of education, seriously and intelligently exploited, the motion picture can equal and even surpass the text-book. Subjects presented in this form would excite greater interest and make more lasting impression upon the memory. As a molder of public opinion and thought, what newspaper or magazine could be as eloquent or carry as much conviction as the carefully prepared motion picture? Its power in this field is well-nigh limitless.

As an instrument for the expression of life, thought and emotion it is the most expressive of the arts. While not so pure an art form as

* *President, The American Society of Cinematographers*

poetry, painting, sculpture, music or the drama, it can partake something of the special properties of these arts and combine them into a unified whole.

The motion picture, an art of time and space, is capable of giving form to all ideas, practical and emotional. It can express life in every one of its aspects. No one knows how far it will go; its only limitation being that of human ingenuity. Unfortunately, in an art so new and complex as this, an art in which mechanical, electrical and optical improvements are being effected daily, there is, naturally, a certain amount of bewilderment as to what constitutes the best usage of this new and ever changing instrument.

Science creates the tools of expression. The artist must learn to use them intelligently, generally a long, slow process with the end, perfection, never quite reached.

The motion picture which tells a story is essentially a work of art. It may be a bad or trivial example of art, a clever or great one, but will always be to some degree a work of art.

What then, constitutes a work of art? How may it be distinguished from examples of mere manual dexterity, from products of science or industry? Art is both a thing and a way. One reason for the lack of clarity and completeness of so many definitions of art by writers on the subject, is that they attempt to define art as one thing, when it is in reality two.

From the hundreds of definitions advanced by man during the past twenty-five centuries we will select a few which we feel are as satisfying and pertinent as they are simple and true.

Lord Leighton, the British painter, said "Art is based on the desire to express, and the power to kindle in others, emotions astir in the artist and latent in those to whom he addresses himself."

Eugene Véron in his "Aesthetics" gives this definition: "Art is the manifestation of emotion, outwardly translated either by a combination of lines, forms or colors, or by a series of gestures, sounds or words, subjected to certain rhythms."

From these definitions we see that emotion is the basis of art, but not the whole of it. Art is also a way, a manner of expression, and the quality of this expression serves as a measure of art.

A complete work of art consists first, in the feeling of certain emotions; second, in the expression of these emotions by lines, forms, colors, gestures, sounds or words, subjected to certain rhythms or measures, so organized that others to whom these emotions are addressed will be stirred by what they see or hear and experience the same emotions.

Unless we are at first emotioned, or stirred by certain scenes or situations, we will never have the power to move others by a representation of these scenes or situations, regardless of our manner of presentation, our knowledge of art, stage-craft, story construction, etc. We may excite a certain admiration by our technical skill, but we will never make a deep impression, because we felt none.

Contrawise, to fully express your emotions you must have certain experience in the practice and knowledge of the laws of your art;

for, regardless of the strength of your feeling, loftiness of your thought, you cannot paint a great picture, compose a sonata or write a good book or play unless you are skilled in the practice of those arts.

The motion picture which tells a story endeavors to awaken certain emotions in an audience; whether these emotions be of mirth, delight, sadness, terror, or a mixture of them all, does not matter, since it expresses or endeavors to express emotion, it is a work of art. The manner in which it accomplishes this is a measure of its artistic quality.

A motion picture can tell a story and not be a work of art only when it is unmistakably an imitation of some other picture or play, for imitation is no part of art. Art is creation. A copy, however skillful or perfect it may be, is not a work of art. A photographed play, regardless of the popularity it may achieve with the public for the quality of its drama or comedy, the skill of the players, the excellence of the photography and sound recording, could not in any sense be considered a work of art, because it has created nothing, is merely a reproduction of something already existing.

Only when it tells a story in the language of the cinema: when it creates new values and emotions, and presents them in a manner unique, peculiar to itself, can a motion picture be called a work of art. The quality of the emotions presented, and the manner in which they are expressed, determines whether it is trivial or great art.

While we have endeavored to show that a motion picture is essentially a work of art, we are aware that no one considers the creation of motion pictures to be anything but an industry.

A motion picture is a complex product, the fabrication of which requires a large and varied group of specialists, the construction of huge, expensively equipped studios, the employment of scores of carpenters, painters and others to build the required settings, thousands to work in them, magnificent theatres in which to exhibit the pictures.

As all this requires the expenditure of vast sums of money, it is but natural to think of the motion picture only as an industry.

The need for the industrial organization that has been built around the interesting but still questioned art of the motion picture is self-evident; for, to it the motion picture owes its present state of development, its dominant position in the world of entertainment. On the other hand, this industrial organization of the motion picture would never have thrived and progressed to its present powerful state had it not been for certain notable examples of motion picture art.

For example: What was the motion picture industry before the advent of the great picture "The Birth of a Nation?" Every great picture that followed has served to bring thousands of new patrons to the theatres—and keep them coming, thereby increasing the revenue, stabilizing the business, placing it on such a firm foundation that capital could be expended in prodigal sums with the assurance that the investment would be safe and yield generous returns.

Numerous critics of the methods of making motion pictures have deplored the waste which they saw or felt existed. They were quite sure that motion pictures could be made efficiently and without delays, loss of time or money. Sausages and automobiles were made that way, why not pictures?

Alas! These critics were somewhat superficial in their analyses. They did not delve deeply enough into the matter. Motion pictures, if quality is but of slight consideration, can be produced almost as efficiently as sausages; but to make a motion picture of quality, with feeling and style and accomplish this with some degree of industrial efficiency, is indeed a task. The executive who can accomplish it is a most unusual man. He must be a combination of artist, psychologist, business man and organizer with a keen understanding of human nature, artistic and commercial values and public taste—with the vision and force to correlate them; because perfect coordination of the different elements of picture making is the only secret of producing quality efficiently. As a motion picture is or should be a work of art, it must express unity.

Plato said: "Beauty is variety in unity." At the time this statement was made beauty and art were practically synonymous terms. We have unlimited variety in a motion picture. Unity is the quality desired, the thing to strive for, as no motion picture can qualify as a meritorious work of art without it.

When we consider the various elements that enter into a complete motion picture we will gain some idea of the difficulty of securing this greatly desired quality. The motion picture of today is composed of five principal elements. These are: the story, cast, settings, photography and sound. The term direction, used by certain critics, is not one of these elements.

The director of a motion picture is, or should be, the co-ordinator of the different elements that compose it. He should take them all and obtain unity. The extent to which he succeeds is the measure of his ability. A good director should be, first, a man of vision who can see the picture as a whole and in detail, knowing the relation of one part to the other. Second, he should have sufficient knowledge of the different elements so that with them he can express the principal ideas of the story in a manner to awaken the desired emotions in the audience to whom the picture is addressed. Like the director of an orchestra, who need not be as accomplished a pianist or cellist as those of his orchestra, he must know the value and relation of each element to the other in order to achieve the desired effect.

The writer, actor, set designer, cinematographer and sound man, while required primarily to be experts in their particular fields, should have sufficient knowledge of the tasks and problems of each other to intelligently cooperate for the good of the picture as a whole.

A factor not included in the five elements outlined above, one that makes the sixth, when it is used, is color. The demand for color photography increased to an almost unbelievable extent after the advent of sound and is steadily increasing. No doubt the incongruity of black and white images speaking lines and singing songs like living beings created a demand for a greater illusion of reality. This color photography helps to supply.

Public demand is not expressed audibly. The producer must guess at what the public wants and endeavor to supply it. If the public reacts favorably he has guessed correctly. Those who study the motion picture felt that the introduction of sound made color a necessity. That the public feels this also is evidenced by the fact that color is a real box office attraction.

Color cinematography at present leaves much to be desired, but progress is being made steadily, especially in the scientific branch of the work. I hope that the artists, those whose task it is to use these ingenious processes to advantage, will not remain too far behind.

The study of color is a most difficult one. Its complexities are best appreciated by those who have really studied and endeavored to master it.

Three-color cinematography (the ideal of all inventors of these processes) suitable for projection in large theatres, has so far not been achieved. Just how long it will take to realize this hope and make it a practical reality is difficult to forecast. The present two-color processes, deficient as they are in rendering the full color range of the spectrum, afford great opportunities to those capable of understanding them. As to what heights of beauty and delight color cinematography can rise, I will quote a passage from that great French art critic, Elie Faure: "Who can foresee the destiny of an instrument like the cinematograph. Can one imagine the power of lyric exaltation which might be given to the mind by a succession of colored images painted by a Michelangelo or a Tintoretto, a Rubens, a Rembrandt, a Goya or a Delacroix and precipitated into the drama of movement and of time by a registering apparatus."

Color cinematography will play a great role in the future, in influencing public taste in the choice of dress, household furnishings, wall and floor coverings; will make the public color conscious, teach them something of color harmony, of the effect of complementaries, altogether have an influence which we who are too close to our subject generally overlook.

The enlarged screen is another development growing out of the sound impetus. Two years ago it would have been virtually impossible to have made any progress with an idea such as this, even if a perfect illusion of depth were obtained. Today everyone in the motion picture industry is highly interested in its development and the public reaction to it. The problem confronting the industry at present is what proportions will be the most effective, pleasing and practical?

The reasons for the large screen are so many and so involved that it would be impossible to even sketch a brief outline that would properly fit into an article of this kind. Some attention could be given profitably to the proportions advanced by Jay Hambridge in his work "Dynamic Symmetry" and others on this same subject, as being fundamentally sound, since they are based on Nature's laws.

I am sure many producers were actuated in their choice of proportions, primarily, by a desire to approximate the proportions of the average theatrical stage. Just why the motion picture any longer should attempt to imitate the stage either in proportions or technique is difficult to understand.

At this point I will venture a prophecy. The ideal screen, the screen that the near or distant future will evolve, will be a great circle, filling the entire proscenium arch of the theatre. Inscribed within this circle will be the picture, of the size, shape and proportions that best frame it. The sizes and shapes will change at will, whenever necessary. The eyes will never grow weary as these changes will furnish a pleasurable motion and variety, an interest aside from that which the drama or comedy will contain.

The change to this type of screen, which I feel is the ideal one, as it provides an unlimited field for the imagination, will be accomplished by a slow, evolutionary process. It will require a far greater sense of values, dramatic, psychological and aesthetic, than we at present possess; a richer and altogether different method of telling a motion picture story. But since so much remains to be accomplished with the material we furnish the present screen, we should learn to walk before we attempt to run.

The motion picture as a medium for story telling is unsurpassed, it affords boundless opportunities to the imagination, there is no limit to its power.

Why, then, are stories told by motion pictures not more interesting and novel? Why in an art so modern, so progressive technically, should the methods of telling stories peculiar to other arts, such as fiction and the drama, be employed and considered good?

Solely because so many understand these methods and know them to be safe, while so few really understand this new art of the motion picture.

D. W. Griffith undoubtedly contributed more than anyone else, to enlarging the narrative power of the screen in raising it to new emotional heights.

Murnau and others contributed greatly to the creation of new aesthetic values, in manner of story telling, in evoking moods, providing new and pleasurable movements and transitions, giving the temporal phase of the motion picture a meaning it never had before.

For their contributions to its art these men will always be honored in the history of the motion picture. Mr. Griffith is especially assured of immortality.

All stories of the life and emotion of man are not simple, some are necessarily complex, especially those which have a theme, yet only simple stories seem to be successful on the screen.

Is the motion picture capable only of telling a simple, one-channel story, is this not an arbitrary, unnecessary restriction imposed upon it simply because we have been too conservative to ask it to do more?

The stage, because of certain limitations, the immobility of its settings, the necessary division of a play into acts, is restricted to the one-channel type of story.

It cannot achieve the freedom of a novelist who can develop a theme through a principal and many interesting, related channels, all advancing toward a desired culmination.

This, the screen can accomplish, is in fact in some respects, a better medium for the complex story than the novel, its only limitation being that of time.

No picture, however great, should require much more than two hours for its showing, but so much (with careful selection) can be told in that length of time.

Could one adequately picture, for example, the drainage of the Mississippi Valley simply by following its principal river, the Mississippi, from its source to the point where it empties into the Gulf of Mexico, what of the Missouri, Ohio, and other rivers that flow into it, that contribute so much to its greatness?

It is safer, of course, to follow the principal channel, we are not likely to be lost in doing so, but by pursuing this course, are we not presenting only a narrow two-dimensional view of the subject? Can we not suggest and portray infinitely more with this great, four-dimensional instrument, the motion picture?

The law of progress is such, that a richer story telling technique must be evolved in time by the cinema; a technique based upon its essential nature. Methods peculiar to other arts and based upon their limitations, that do not suffice, will be abandoned.

The full power of the motion picture will begin to be felt only when writers, directors, producers and others understand it to be what it really is, the most modern and expressive of the arts, the only four-dimensional art thus far invented by man.

To those who take the motion picture seriously, who believe in its future, who sincerely wish to progress in this art, the Cinematographic Annual is offered.

We have felt for some time that there was need for a book such as this; a book that would make a sincere effort to advance the art and science of cinematography.

Without doubt much desirable material will have been omitted in this, the first Annual. It is but natural to make some mistakes in a first effort of any kind, but from year to year we hope to improve; to make this publication a most valuable and useful adjunct to the profession; a book that will be eagerly awaited by everyone interested in this art.

The hopes of the American Society of Cinematographers are bound in this volume. Twelve years of effort (a long time in this business) are climaxed in the publication of this book.

We earnestly hope you will like it and derive benefit from its perusal.

Hospitality Elwood Bredell

CINEMATOGRAPHY an ART FORM

Lewis W. Physioc

OUR discussion is not so much designed to inspire, in the layman, a respect for the fascinating art of which the cinematographer may boast. It is rather intended as a direct appeal, to those who profess this beautiful art, with the idea of impressing them with the degree of responsibility which devolves upon any one who undertakes the study of any form of art.

We address those who have a deep seated love for beautiful and noble things; who have a real desire for artistic expression, coupled with an ambition that their mastery of this may win the approval of those who are able to judge. This is, indeed, a responsibility.

This responsibility is premised on the fact that the laity, or the public, is the direct patron of the form of art we are discussing, a very generous patron and is, therefore, entitled to the most serious efforts of those who depend upon this patronage. The time has passed for "crank turners" and insincere retainers of a popular novelty, as was once the case of the motion picture industry. This business of making motion pictures has developed into a great art. With it has come an acute critical sense which embodies a demand for greater excellence of performance.

If we trace the history of the arts, from the early Egyptians to our present motion picture, we are impressed with the thought that there is no form of art that can compare with the motion picture in its possibilities for influencing the popular taste and culture. This is due to its wide distribution. Where there is one person who might attend the art gallery, the concert, a lecture or the opera, there will be a thousand attending the movie show. Consequently, the same critical development will result, in regard to the motion picture, as would be the case with those who frequented the aforesaid attractions. What is far more promising, our public schools and universities are devoting more time, than ever before, to the development of the aesthetic mind —art appreciation, a taste for beautiful things. Therefore, the responsibility of the cameraman, or any one engaged in the making of motion pictures, is readily perceived.

Now the very word "Art" implies an order of talents and elements that are not generally associated with indifferent efforts or lazy intellects. Bouvier, the great instructor, has said. "Imagine not that the profession of an artist is that of an idler; on the contrary, it is of all occupations the one, perhaps, that requires the most activity; for one is constantly engaged, if not with the art itself, at least with its materials."

All true artists will tell you, that if the study of art were not, in itself, replete with charms, it would be a very painful pursuit. The art of photography, alone, requires so many precautions, so many things to be foreseen and calculated, such tedious minute adjustment that those exacting labors are only relieved by the delights of the final results. We may further quote; "happy is he, not who has the fewest obstacles to encounter, but who has the most spirit and perseverance to surmount them, or the resignation to submit to disappointment when the difficulties prove insuperable."

If we must justly fix the responsibility of the cinematographer, we must classify his position among the arts.

Definition of Art.

It is no easy matter to find a satisfactory definition of art.

The ancient philosophers have defined it as being anything that is apart from nature but having been produced by natural laws; that anything but nature was artificial and the result of art. Others contended that even nature, itself, was artificial and assumed the one great, generic idea of art in the conception of the Creator as the initial and Divine Author. A noble scheme, indeed, for an artist to fashion his ambitions upon. John Ruskin's writings are conceived upon a plan of equal reverence and attempt to identify aesthetics—or the love of art—with our moral perceptions. In his "Ideas of beauty," he claims that beauty is spiritual and typical of Divine attributes.

Dr. Samuel Johnson excited considerable discussion when he defined art as "the power to do something that is not taught by nature or by instinct." This naturally suggests a distinction between man with his marvelous ingenuity to create many things and the various animals and insects that have power to produce various works independent of nature, performances that inspire the awe of man, challenge his reason to explain and tax his ingenuity to imitate. How often have we looked, in wonder, at the spider weaving its web; the beaver building its dam; the labors of the bee; the industries of the ants and the nest building of the birds, all of which seem to embody the first principles of art, using the forces of nature to produce necessary utilities. Here we have a picture of man matching wits with the instincts of bugs and animals, a train of thought that seems to carry us back to the aforesaid concept religioso, "The Great Artist of Nature."

These speculations have naturally demanded a modified definition of art, one that will adjust this distinction between man's rationalism and animal instinct. We, therefore, account for art as being that which is produced by *man* using natural forces. But even here, our subject does not end, for the more we develop it, the stronger becomes our conviction that we cannot divorce art from nature. The scientist now comes into the picture and shows us that no matter what we may produce by natural laws, we necessarily borrow from the realm of science, a fact which introduces the ancient claims to honors between the "arts and sciences." However, let the artist enjoy this thought: the more we try to define his position, the higher we elevate his pedestal for the dignity of his position is confirmed by the complications and extent of these speculations. But let the artist not forget that the claims of science do not lighten his burdens for if science insinuates itself into art, the artist must master those branches which are necessary to his profession. Therefore, Mr. Cinematographer, think well of your complicated curriculum and you may realize the responsibility of your vocation.

Origin of Art.

The history of art is one of the most important branches of the history of mankind. What we know of ancient history is largely due to the work of archeologists who, through their rummaging among the productions of ancient man, have furnished a great deal of the historian's material. Those antiques, which they have unearthed, represent the earliest forms of art and establish the degree of development of civilization. They also furnish the fundamental idea of two well defined forms of art: First, that example which was founded purely on the proposition of utility. The second form was a natural progression of the first and inspired by the love of expressing beauty for its own sake. It is accounted for by the fact that life made more easy and interesting through the development of utilities, the æsthetic sense was aroused.

This state of culture introduces such forms of art as sculpture, painting, music, poetry, the drama and, lastly, motion pictures; all of which have their origin in that deep rooted desire—which dates to that aforesaid awakening of the æsthetic sense—of reproducing or imitating those things which are pleasing.

In tracing the origin of the arts, it is interesting to picture to ourselves the ancient cave man fashioning a spear from a piece of stone. He needed the thing to protect himself from wild beasts and his not much less ferocious brother. Next, he ornamented it with streamers of strips of skin, which made it pleasing to look at. His spear was then the envy of his fellows. Here we have the primitive idea that any form of production must appeal to the æsthetic sense, of combining beauty with utility. What is more important, it suggests the natural tendency of man to improve the ideas of his fellows and is the vital factor in the development of the arts. "A potter thumped his wet clay" and molded a vessel which, along with its usefulness, was much admired; but another man devised a wheel and took the same wet clay and turned it into a pot of more perfect symmetry, a form of exquisite beauty. No other man could mould a pot as he did. He was proclaimed an artist because his individual skill had broken away from the old method of thumping out a crude unshapely thing. Our fancy furnishes the true conception of the high forms of art and suggests a more satisfactory definition of those forms previously mentioned and which are entirely considered from the sense of delight and amusement. It suggests that we narrow the definition of art as *the product of human ingenuity, more nearly addressed to the emotions, and wherein individual genius determines the degree of excellence.* Therefore, Mr. Cinematographer, beware of that competitor of yours, that studious dreamer who goes about looking for beauty in all things; who borrows from science what he feels he needs. He will even call upon the humble mechanic when occasion requires. He will utilize any natural force to aid him in putting on the screen that something which burns within him. He will lead you a merry race, for he is an artist.

The Elements of Art in Cinematography.

Let us now consider what a cinematographer must study to distinguish himself in his vocation. To again quote the authority: "what must I do in order to know, is art subservient to science; what must I know in order to do, is science subservient to art?"

Lighting

The lighting of motion picture photography has developed to a very high degree and it is not boasting to say that photography, in general, has been influenced and improved by the work of some of our talented cinematographers. The use of artificial light has revealed marvelous possibilities to all photographic enthusiasts. We feel that this fact has resulted in the general use of artificial light by portrait specialists and commercial photographers. However, there is yet much to be learned, greater excellence to be attained.

It is probably far-fetched to talk of a cinematographer studying drawing or painting, especially some of the busy ones who are committed to such long hours. But lighting is so closely associated with the thought of painting that it would be very fine if the cameraman could spend some of his spare time in the academies. If not to learn to draw, at least to enjoy the association of the masters and subject himself to the influence of the art world traditions and profit by the accumulation of knowledge that has come down to us through the ages. It is through such association that we cultivate the artistic sense; when we begin to think with the artist's mind; when we begin to see beauty that was formerly obscured by a nescience that had not been illumined by the light of aesthetic studies.

You may think that we lay out, for the cinematographer, a rather severe course of study, but let us recall Bouvier's admonition, that any form of art is an exacting school and that the life of an earnest artist is a busy one. There is nothing that demands such a long and tedious apprenticeship. Consider how long a painter must toil, how much valuable material he must waste, how much discouragement he must suffer before his work can bear intelligent criticism. Think of the persistent tutelage of a Kreisler before he can graduate from a mere fiddler to a virtuoso. There was a day when most anybody could go out with a camera and bring back something that would be fairly acceptable to the patrons of a novelty, but not at the present time—we have gradually evolved a great and beautiful art from this novelty and its patrons have become connoisseurs. Therefore, motion picture operators must submit to the same rigid training that the other arts demand.

If, in contemplating this severe schooling, we are inclined to be stingy with our time, become discouraged with the meager results, or if we fall into the habit of easy enjoyment of the sometimes generous earnings accorded the clever ones, we may be aroused to greater efforts by reviewing the energy of some of those who have gone before. We may well emulate such a man as Leonardo da Vinci who was probably the most generally cultured man of whom we have ever known. There was little time wasted by such a man, who lived during a time when general knowledge was poorly disseminated; when painters made their own brushes, ground their own colors, whose wives wove their canvas. How rich in æsthetic enjoyment must have been the life of this one man who was master of all the arts. Consider, also, the labors of Michelangelo, who wrought before the time of steam or electric drills. Think of the mental fortitude of a man approaching a huge block of marble and beginning to chip, with mallet and chisel and never leaving off or tiring until he had completed his design. How many of such works he has left to delight the æsthetic minds of succeeding years; what monuments of colossal industry, infinite patience, consummate skill; what evidence of *little wasted time.*

Now, if the cinematographer cannot study his lighting in the academies, he can, at least, resort to the reproductions of the work of some of these masters whom we love to cite. In recommending this line of study, there is another favorite whom we delight in mentioning, a name that suggests itself repeatedly, it is that of Gustave Doré, for if there is one man's work that can be taken as the cinematographer's text, it is that of Doré's. His stories are told in our own language of "black and white," are highly imaginative and dramatic and should stimulate anybody's ideas.

The demands upon the ingenuity of the cinematographer, as regards lighting, are evidenced in the ever changing position of his subjects. Unlike the portrait artist, who can place his sitter at will, carefully arrange his lighting, make several exposures, pick the best and retouch the negative and nurse the printing, the movie photographer must provide for every change of position, pose and expression in a single run of film; and this is no easy matter.

Lighting is also so closely related to composition that we may almost consider them together by pointing out the fact that a light effect can often be made a feature of drawing and composition, and it requires a practised eye and skillful treatment to effect this. Very often (especially in out door work) a mere shifting of the camera angle will convert a harsh, ugly shadow into a very pleasing effect of drawing or composition. Sometimes it also happens that the set requirements are so simple that very little possibility is furnished for picture display. In such a case, artistic instinct can supply this lack of beauty by clever arrangement of the lighting. In this manner, we have frequently seen very simple sets made to appear very beautiful. This suggests an element of art that has been grossly neglected—*that of simplicity.*

Where there is too much complication of source and direction in lighting, there is likely to be too much discord in effects and values. If we ever keep in mind natural effects we cannot go far astray. We should not leave so important a subject without mentioning a prevailing fault in cinematography; it is the apparent fear of shadow. We admit that this fear is excusable for if the shadowy portions of a picture are absolutely lacking in luminosity, harsh contrasts will result. The handling of the shadows probably requires the greatest skill.

Composition

A sense of composition is a peculiar natural gift. It may be defined, simply, as an individual taste for arrangement. This taste is exhibited in most every one, from the arrangement of articles on a desk or the housewife's placing of furniture or hanging draperies, to the finer elements in a work of art. But, certainly, this talent may be developed to a high degree by a careful study of accepted rules. Let us be reminded, again, that these rules are merely the result of a classified study of striking effects in the works of the masters of art.

In discussing the subject of composition, we recall to mind, very vividly, an essay on composition by Edgar Allen Poe; and although it is devoted to illustrating the design of a poem or story, it is a beautiful example of how the mind may be trained in assembling the elements of any form of art.

This subject, alone, is so extensive that the mere contemplation of it is enough to convince the aspiring cinematographer that his program of study is a severe one.

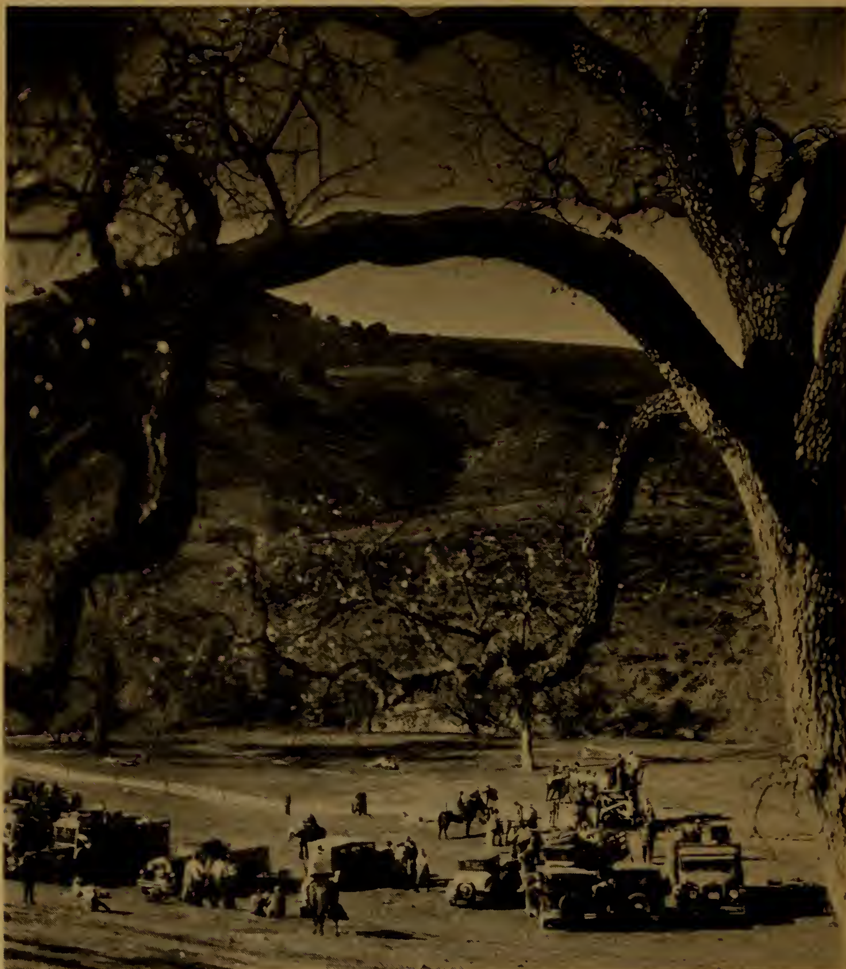
Nor is this all that the cinematographer must know. Let us add, to the foregoing requirements, one of the most complicated branches of chemistry; the problems of color which has been introduced by the use of panchromatic film; the modification of the long used systems of lighting, necessitated by the adoption of incandescent lights in conjunction with the panchromatic film, this same change being also one of the requirements in the proper lighting of the so-called natural color photography; the very diversified field of "trick photography," miniature and process work; then may we begin to measure the responsibility of the cinematographer.

Now, when we review all that we have here discussed, we are impressed by the proof of a very dignified matriculation; yet all this does not confirm the claims to art. We now approach the consideration of a somewhat awesome attribute,—a distinct characteristic that artists have zealously and jealously fostered in the mind. We allude to that something which they inject into their work which distinguishes it from the products of merely technical expedients,—an innate motivation for all they do. They call this *feeling*.

After the artist's work is done, with all the technical elements satisfactorily assembled, he still "feels" that there is something lacking. The painter, before his canvas, squints, with half closed eyes; retires and views it from a distance and various angles and different lighting conditions. He studies it with a dreamy, searching vision. He approaches it with a sudden inspiration and resumes his work with feverish interest,—a little atmospheric softening here, an impulsive splash of color there, the deepening of shadow, subduing a highlight; all of which he knows not why,—perchance it violates all the rules of his curriculum, but he "feels" it must be so. The savants view his work and they, being schooled in the phraseology, say it has "feeling". There is something in it that veils all of the academic mannerisms; there is a treatment of the various elements that marks it with his individuality. Ere we see the signature, we exclaim, "there's a Vandyke! a Hals! an Inness! a Moran!" It is something which that ancient potter put into his work, as he wet his fingers and gently touched the spinning clay, modifying and perfecting the form that might have satisfied most of his brother potters. He gave it the stamp of his *individuality;* he imbued it with his *feeling.*

Now, can a cinematographer justly claim this great attribute? Why not? He is working through a medium capable of individual expression,—susceptible to reflecting moods and temperament. Who can gauge his feelings—this cinematographer—as he squints through his monotonic glass, shifting the lights around, stationing reflectors, maneuvering shades and gauzes, determining the use of lenses and diffusers? Why do critics recognize his work upon the screen? Why do the various players demand his services? Why do producers secure his services by contract? *It is because he is an artist.*

Let him make no mistake about the nature of his profession, and he must, therefore, realize the degree of his responsibility. Let the public, likewise, be persuaded of this, for his work must carry this conviction. Let his employers be convinced of this by the manner in which he discharges the obligations of his high calling.



On Location Elwood Bredell

CINEMATICS

Some Principles Underlying Effective Cinematography

Slavko Vorkapich

CINEMATOGRAPHY, considered as a medium of expression, is comparatively new. It is still experimenting and groping in its search for self-knowledge, in its attempts to find its own way of telling expressively what it seeks to convey. It is hybrid insofar as it imitates or borrows from literature, stage, painting and music; it is unclear and undecided as to its proper style and form.

If, in the old Socratic manner, we ask ourselves a few questions and try to answer them, we may find a clue leading to the solution of the problem.

What fundamental means of expression do we find in the art of painting?—Lines and colors.—And in sculpture?—Forms, volumes.—In music?—Tones.—That is clear. But how does cinematography express itself?—In pictures.—So does painting and photography. Evidently the answer is not satisfactory. So again we ask: What kind of pictures?—Motion pictures.—There, in that one word —*motion*—we have perhaps our clue.

The present article is an attempt to investigate in that direction and to see whether the proper language of cinematography might not be the language of motions.

We shall approach the subject, in a summary way of course, from three different angles: psychological, aesthetic and practical.

II.

AS SOON as the child begins to see, its attention is attracted by anything that moves. There must be something interesting in those vague changes of light and shade and those indistinct shapes that float across the baby's field of vision. Things are a little out of focus perhaps, nevertheless they are exciting because they—move.

For a while the child is only a passive spectator; it watches with curiosity whatever appears on its limited screen, but soon it demands to take active part in the general movement of life. You have to pick it up and carry it around.

Now the panorama swiftly changes; walls, windows and the objects in the room merrily pursue each other around for the entertainment of the little creature. The pleasure of visual change is enhanced by the travel through space of the child's own body. The instant you stop the movement, the baby voices an energetic protest. Obviously there is a keen delight in motion both visual and bodily. The latter is perhaps some pleasant physiological sensation caused by the displacement of the body's center of gravity. But if this is done too violently, as in sudden dropping for instance, an emotion of fear may be produced. Motion, as we see, can be a source of pleasure and also of pain.

With the growth of the child its interest in motion increases. The perambulator, the wooden horse, the seesaw, the swing, the merry-go-round, etc., provide a large variety of motions. These motions have the power to quicken the feeling of life, to produce exhilaration and provide entertainment.

And we never outgrow our infantile interest in motion. From the cradle in childhood to the rocking chair in old age we find in dancing, sports and travel a variety of bodily and visual motions invigorating, entertaining and soothing.

Amusement places thrive on motion. Advertisers use it to attract buyers: barber-poles gyrate, windmills revolve and electric signs do a dervish dance every night.

Modern psychology teaches that our primitive emotions can be sublimated and our reflexes conditioned. In other words, and in the present case, we may create pleasure and entertainment by suggested motions. By merely seeing motion on the screen our minds, conscious or subconscious, may be made to react in a similar manner as in active participation.

III.

IF WE approach the subject from a more aesthetic and philosophical angle we may find arguments which speak in favor of the motion picture as a new form of art.

The existing arts are divided in two groups: *one static and spatial, comprising architecture, sculpture and painting with their subdivisions; and one dynamic and temporal: music, poetry and drama.*

The motion picture is *both*, spatial like painting and temporal—dynamic like music.

This double characteristic harmonizes with the modern scientific concept of Space—Time. It is within the power of the cinema to create its own space and time. It can tie fragments of several different objects, situated in distant points of space, into one organic unity; it can stretch one tragic moment into unbearable suspense. This ability of the motion picture to recreate, expand, contract and transform space and time to its own purposes makes it very much in keeping with the theory of Relativity.

The aesthetic terminology, whenever it attempts to speak of vital values of any work of art, is compelled to use words which are really descriptive of the qualities of motion. In such static arts as sculpture and painting we look for the "flow" of lines, "rhythmical" arrangement of forms, "movement" in composition, etc. In music we find tempo, beat, rhythmical pattern, movement, etc. All these concepts are intrinsic attributes of actual motion. With the motion picture camera at our command we can now have all these not only figuratively but literally. The power of the cinema to embody the principles of rhythm makes it a truly dynamic form of art. And the modern age being a dynamic one, its logical medium of expression should be the motion picture.

Motion is energy visualized, therefore motion is a symbol of life itself. Immobility is death. And yet, there is no immobility—within every atom the infinitesimal electrons keep on whirling.

Our world is infinitely rich in color, form, sound and motion. All, except the last have been used by man artistically to express his thoughts and feelings. Although the oldest of arts—dance—is an art of motions, it is very limited in its scope. It uses only the movements of the human body and of drapery. Now the cinema offers possibilities, almost unlimited, of creating symphonies of visual movement, by using a tremendous range of motions from the violent sweep of a tornado to the delicate drooping of an eyelid.

IV.

TO TREAT the subject from a practical angle without actual demonstration is rather difficult, especially for the present writer who is not a writer but a man used to thinking visually. However, we shall attempt to make a few observations.

The majority of the motion picture public seems to prefer pictures of action to those of mental subtleties. This is natural and perhaps closer to truth and the logic of the medium; for action is motion in a broader sense. But, for purposes of cinematography, the meaning of the word "motion" should be limited to only a certain type and certain views of actions. There are objects and persons which "photograph well", and there are motions which "cinematograph well", that is—expressively. As there is in music a difference between tone and noise, there is in motion pictures a difference between any kind of movement and—shall we say—cine-motion.

In almost every motion picture are to be found moments in which there occur some particular movements imbued with such intense life and power that they seem to carry us along, regardless of the meaning and the specific point of the story. What is there obtained perhaps accidentally should be sought, studied and used consciously.

The insistent emphasis on motion in the foregoing discussion may have created in some minds the wrong impression that the perfect picture would be the one in which the camera constantly perambulates and the actors wildly gesticulate or perform a sort of breathless ballet. Nothing of the sort. We must remember that an essential element of rhythm is—*pause.* Also, cinematically speaking, motion is not only actual movement but also certain types of *visual changes,* namely: lap-dissolves, fades, changes of focus, changes in iris, rhythmical cutting, etc. The last mentioned is one of the most important elements of expressive cinematography. A sequence of scenes—even static in themselves—cut in definite lengths in such a manner that we rhythmically feel each jump from one scene to another, has sometimes the capacity of creating a feeling of intense vitality.

There are two opposite methods of being expressive: by using a strict economy of means or by piling up a wealth of impressions. Some scenes demand a simplicity and directness of style, while some require an abundance of images. Into the latter method belong the "camera angles". By making the camera mobile and omnipresent, in other words, by shooting the same scene from different interesting angles and by showing a variety of views related to the scene at hand one could make it more vivid and impressive and perhaps save it from possible dullness.

Now to come back to actual motions. Space does not permit a thorough analysis, so we must be satisfied with some general remarks and a few examples.

Like lines, colors and sounds, different motions have different emotional values. In the graphic arts horizontal lines usually suggest rest, peace, serenity; vertical—dignity, strength; curves—fluidity, warmth, femininity, etc. Something similar is to be found in motions.

The following examples should not be taken as formulas for effective picture making, but merely as general observations. The golden rule is that there is no rule. We know that in any form of expression the values of individual elements are greatly affected by their correlation.

If, for instance, we open a picture with the camera perambulating into the scene we may create the effect of drawing the audience into the picture and thus making it participate intimately in the story from the very start. The reverse motion, receding from the scene, may be effectively used at the end of a picture. This would create a sensation similar to those produced by the last diminishing notes of a musical composition.

The ascending motion may help to express aspiration, exaltation, freedom from matter and weight. In treating a religious scene, for instance, we may learn something from the lofty, vertical, ascending lines of the Gothic cathedrals. From the view of a kneeling devotee we may pan up to a sacred image, we may show views of candle flames and upward movement of the incense smoke, and also we may include an effervescent fountain in the monastery garden.

A cheerful mood may be enhanced by the revolving, circular motion. Most of the devices in the amusement places are using this motion to make life merry for the customers. Many folk dances are performed in circles. The same motion is also expressive of another form of exuberance, that of mechanical energy, as in revolving wheels of machinery.

The diagonal, dynamic, motion suggests power, overcoming of obstacles by force. A battle sequence may be made very effective by using short sharp diagonal clashes of arms; flags, guns, bayonets, lances and swords cutting the screen diagonally, soldiers running uphill, flashes of battle shot with slanting camera.

There are many such fundamental expressive motions and the possibilities of their combinations are unlimited. To mention briefly only a few more:

Descending motion: heaviness, danger, crushing power (avalanche, waterfall, etc.)

Pendulum motion: monotony, relentlessness (monotonous walk, prison scenes, caged animals, etc.)

Cascading motion, as of a bouncing ball: sprightliness, lightness, elasticity, etc. (Douglas Fairbanks.)

Spreading, centrifugal motion, as the ripple on the surface of a pool after a stone has been thrown in: growth, scattering (mob panic scenes), explosion, broadcasting, etc.

Indeed a whole grammar of motions could be written, analysing the elements of the cinema language. And by means of that language many new and wonderful things are yet to be told.

I firmly believe that there is no scene in any picture which could not be made more effective, emotionally—more intense and artistically more lasting by imparting to it the proper rhythm and devising some significant motion which would best express the given mood.

A perfect motion picture would be comparable to a symphony. It would have a definite rhythmical pattern, each of its movements would correspond to the mood of the sequence and each individual phrase (scene) would be an organic part of the whole. And like a symphony it would be interesting at every moment of its development regardless of the meaning or story it has to convey. In other words: *a motion picture should be visually interesting even if we entered the theatre in the middle of the performance; we should be visually entertained even if we did not know the beginning of the story.*

In the present article the subject of cinematography has been treated only from the visual point of view, which will always remain the most important one. The invention of sound devices has opened new and almost unlimited possibilities. To discuss these in relation to the theory here expressed would require much more space than is permitted. But we can mention the obvious fact that the sound can be made to harmonize audibly with whatever is given on the screen visually, and that it could enhance the cinema's original power of expression to an immense degree.

There is no cause for alarm if the present pictures seem to have lost some of the tempo they formerly had, no matter how primitive it was. This is a period of experiments and adjustments. Eventually the sound apparatus will—like the camera—evolve from a merely reproductive into a creative instrument.

EASTMAN KODAK COMPANY

ROCHESTER, N.Y.

March 27, 1930.

Dear Mr. Hall:

I am happy to take this opportunity of wishing success to the American Cinematographer's Year Book. Those who are interested in the future of the motion picture art must regard with favor every legitimate attempt to promote the interchange of technical information among motion picture technicians both professional and amateur.

It gives me pleasure that you have asked our organization to prepare for the Year Book an article on the evolution of film.

Yours very truly

Geo Eastman

Mr. Hal Hall, Editor
The American Cinematographer
Hollywood, California

THE EVOLUTION OF FILM

THE first American close-up had little to do with emotion. It was purely a matter of the intellect: Miss Dorothy Catherine Draper had to face the camera for about a quarter of an hour—a feat of sheer mental control that none of our current close-up charmers are compelled to undergo in these days of hyper-sensitized panchromatic motion picture film.

Miss Draper's portrait, made in New York ninety years ago by her brother, a professor at New York University, was a Daguerreotype. Everyone is familiar with those illusory views of our worthy, if somewhat angular, ancestors.

The Daguerreotype process was the first that made photographs with a real degree of success. Miss Draper suffered from being a pioneer. Only a few years after her first scene had been shot, the taking exposure was reduced to a matter of only a fraction of a minute—and that great Victorian institution, the head clamp, did the rest.

Daguerre's was not a film process, but it was an early forerunner of film. The sensitive surface in the camera was a plate of silver darkened by iodine fumes. The plate was exposed and then held over a dish of gently warmed mercury. The mercury vapor clung to the parts of the plate where the light had acted. The silver iodide of the sensitive surface was then dissolved away by "hypo," just as negatives are "fixed" today, and the light areas of the scene that had been in front of the camera appeared mercury-white, whereas the dark areas appeared in the black metallic silver of the surface of the plate.

The first film, in the sense of a transparent and flexible sheet, was—paradoxically enough—far from transparent. Fox Talbot, a young English photographic pioneer, made pictures on paper coated with silver iodide instead of on silver coated with iodine, and he used no mercury in the process of development. Therefore, his image was a negative. The ingenious Mr. Fox Talbot greased the paper negative to permit the light to go through it, and then, by an extremely long exposure, he printed the first positive.

Every invention accomplished sets the foundation for another. From Fox Talbot's scheme other men devised the use of glass as an emulsion support. First wet plates, then dry plates, but both on glass, continued to be used until George Eastman, stimulated by the disadvantages of heavy, breakable glass as a photographic medium, was finally successful in producing an equally transparent emulsion support that was at the same time flexible, light, and unbreakable.

The Eastman story is a most romantic one. Working over uncharted ground, George Eastman manufactured dry plates to supplant the inconvenient wet ones currently in use when he became interested in photography. Then he devised the roll-film idea which lead to the Kodak.

Throughout the '80's, while the Kodak idea was forming, the missing link was a satisfactory film substance. Paper was the material of the first roll film arrangement. Going back to Fox Talbot's scheme, Mr. Eastman's little organization for a while greased the negatives and printed through them. The grain of the paper, showing slightly was enough of a defect to prevent contentment with this procedure.

While a small-scale business was carried on with the use of the greasing method, Mr. Eastman and his helpers were experimenting with the possibility of stripping the gelatine emulsion from the paper base. This was done under water, after the negative had been developed and fixed, and the delicate skin of emulsion bearing the photographic image was transferred to an additional thickness of gelatine for strength.

The stripping method was perfected and applied: yet, even before it came into use, efforts were being made to find a film base more sturdy and one which should not entail the complicated and expert efforts involved in stripping.

The search long eluded success. But, in 1889, Mr. Eastman and his organization finally succeeded in making commercially practicable the present cellulose base—by dissolving cotton, previously nitrated, in a solution of denatured alcohol. Like most basic inventions, this discovery seemed quite simple when finally it revealed itself. Yet the Kodakers who press the button for snapshots, equally with the cinematographers loading 1,000-foot rolls, seldom have an opportunity to look behind the scenes, into the time when there was no film base, at the small group of men tirelessly experimenting to make a material even the possible existence of which they were not sure of.

The discovery of film not only revolutionized photography, but also it made motion pictures possible. Edison, struggling in his West Orange laboratory to devise a machine which would reproduce motion visually, heard of the Eastman discovery in Rochester and sent his famous assistant, Dickson, to investigate it. Dickson took a strip of the new transparent and flexible substance back to West Orange and showed it to Edison.

The man who was to invent the movies looked at it for a moment, then said: "That's it—we've got it—now work like hell."

The purchase memorandum for the first strip of film is still in the files of the Eastman Kodak Company, dated September 2nd, 1889.

All the experimental film supplied to Mr. Edison was negative film. The characteristic of negative film is its speed. For printing positives it appeared desirable to have film with an emulsion prepared particularly to reproduce images with the maximum of definition at the sacrifice of speed, which is not essential for the uses of positive film. Consequently, special film for printing positives was made—in 1895. The output of positive film from the Eastman factory in that year was 21,663 feet. That amount contrasts with the current Eastman production of standard motion picture film of about 200,000 miles a year, the bulk of which is positive film.

As the motion picture industry progressed, the Eastman Kodak Research Laboratories were established (1912) in order to keep the technical achievements of the industry abreast of the artistic developments. Laboratory researches have included the cause of electrical markings on film during exposure, improvements and increased efficiency of developing and printing processes, the method of waxing the edges of new prints to prolong their life, and many investigations along similar lines. In addition, the Laboratories have been responsible for the introduction of several new and specialized types of film as the motion picture industry has moved on its forward march.

Safety film, for instance, with slow-burning base, was made available. Its principal use is for prints—such as industrial motion pictures—that are to be projected in auditoriums lacking fireproof projection booths, and for home movies.

In 1921 tints were added to the positive film base. Nine colors were made available, and the industry rapidly turned from black and white to the greater expressiveness and the more pleasing appearance on the screen made possible by the addition of hues. In the same year the so-called "news positive" was introduced, the characteristic of which was a thinner base. News prints are required for exhibition for a shorter duration of time than feature prints, and consequently, since they receive less wear, a thinner base is possible.

Exigencies of the industry's growth required that more than one negative of each picture should be available, for considerations of precaution against loss as well as to increase the facility with which a large number of prints could be made. As a result, duplicating negative film was evolved in 1926. Its emulsion is especially suited to the purpose.

For the past ten or twelve years panchromatic film, which reproduces all colors of the visible spectrum, has been manufactured and used in a limited way. Not until 1927, however, did improvements in this type of film make it apparent to motion picture producers that superior quality negatives could be obtained by the use of panchromatic film. In a remarkably short space of time thereafter panchromatic film almost completely replaced the older type of negative. In 1928 the Eastman Kodak Company produced a panchromatic film, called "Type 2," which was worked out to give the best results with incandescent lighting when that type of illumination assumed the disposition to displace previously used lighting systems.

The advent of sound with motion pictures made many striking changes in the industry. One of the most marked was to throw out the tints that had been almost universally used for motion picture prints in the preceding years and to bring in the original black and white instead. The reason for this was that the tints then in existence had a strong tendency to interfere with the passage through the sound track of the light to which the photo-electric cells were most sensitive. As a result, tints in prints seriously distorted the sound reproduction. Consequently tints were abandoned.

Laboratory technique, however, was more than equal to the situation. After months of research, the Eastman Kodak Research Laboratories produced a series of sixteen tints and a neutral "argent" to restore to the screen the brilliance it had lost. The new tints interfered with the sound reproduction to no perceptible degree. Use of the so-called "sonochrome" tints is becoming widespread. Probably the most distinguished example in 1929 was "The Taming of the Shrew." This picture used a single, uniform tint throughout to suffuse the picture with a warm Italian atmosphere. A table of psychological values for Sonochrome tints has been worked out on a scientific basis in the expectation that changing tints may be used—where natural color is too expensive—to influence the mood of the various scenes of a photoplay.

Hyper-sensitization of panchromatic film, which increases the red and green sensitivity of the film three to four times, is a comparatively recent important development in the interest of greater speed.

It is an interesting commentary on the scope of modern science that the technological aspect of the movies has kept abreast of the dazzling changes of recent years by providing film equal to every need.

The manufacture of film is one of the most interesting large-scale industries by reason of the fact that, despite huge production, laboratory standards of quality and super-cleanliness are necessary. Variation of a tiny fraction of an inch in the thickness of film might mean scratches in projection, and the tiniest particle of dust dried into film in the course of manufacture might, under the magnification of the projecting lens, become a large blotch on the screen. Manufacturing surroundings that are free from dust and dirt are essential.

Kodak Park's green acres are an effective barrier—a broad no man's land against the enemy of dust along the highways. The paved streets in the plant are not merely sprinkled, but are flushed at high pressure frequently. The freight cars that move through Kodak Park are hauled by steam locomotives that are fireless and therefore emit neither smoke nor soot.

Interior surfaces of film-making buildings—walls, ceilings, and floors—are constructed of materials that can not disintegrate and cause dust. The air present in the various departments is washed and filtered to stop elusive particles. Vacuum cleaners in the hands of cleaning squads go over every inch of exposed surface several times daily. "Round" corners leave no hiding places for dirt and make easy the cleaners' task.

Even the matter of clothing is considered. Street clothes may not be worn in certain departments, but instead are changed outside for laundered suits which go frequently into the laundry maintained at the plant for the purpose. Boots are exchanged for rope-soled shoes that will not by any possibility grind dust out of the floor surfaces.

The base of all film is a cellulose product. Cotton supplies this necessary ingredient. Kodak Park uses more than 5,000,000 pounds of cotton in a year. As cleanliness and purity are of prime importance in all film-making, weeks are first spent in washing and drying the cotton which goes into the making of the transparent base. All vegetable gum and other impurities are removed with caustic soda in large rotary vats. For eliminating the moisture the cleansed cotton then passes through huge dryers.

The next step in film-making is treatment of the cotton with a mixture of nitric and sulphric acids to render the cotton soluble later in alcohol. This changes it to what is technically known as "cellulose nitrate." This process, while not altering the physical appearance of the original cotton, does change it chemically so that it will be soluble in the various mixtures in which it will be deposited.

When nitration is complete, high speed rotation of centrifugals separates the excess acid from the cotton. Next the nitrated cotton is immersed in large tanks of water and drained and rinsed over a period of weeks. Other centrifugal wringers spun at high speed remove all the moisture before the cotton is ready for the solvent.

Huge drums or barrels are used to bring about a thorough mixing of the cotton and the wood alcohol which is the chief solvent. The drums are sealed and revolved for a period of several days, and the solution which results has the consistency of syrup or extracted honey. This is then pumped through mechanical filter-presses to render it absolutely free from any remaining dirt, dust, or foreign particles.

This "dope," as it is called at Kodak Park, is next piped to air-tight tanks and is held ready to be converted into sheets. The solution, now glass clear, is poured on the surface of great polished wheels which run continuously night and day. One of these wheels now produces twenty-five times as much film base as the whole of the first Eastman factory.

As the film must be uniform in thickness, this operation calls for extreme care in handling, and the variation in thickness in a sheet 2,000 feet long and 3½ feet wide is imperceptible except with the most delicate instruments of measurement.

For easy handling the base is rolled on a core in large rolls similar to printing paper rolls, and in this form, after a period of aging, it is sent to the sensitizing rooms.

Silver is the active element in the sensitizing material, called the "emulsion," with which the film is coated. The pure silver bullion comes in bars, each weighing about 42 pounds. The bars are dissolved in nitric acid in porcelain dishes, and after crystallization pure crystals of silver nitrate are obtained. Other ingredients of the emulsion are potassium iodide, potassium bromide, and gelatine. If these bromide and iodide salts are dissolved in water, and if to the solution thus prepared silver nitrate solution is added, a soluble yellow salt is precipitated which is very sensitive to light and which turns black after a few minutes' exposure.

If this solution were coated on the base, the film would have very little sensitivity, and for all practical purposes it would be worthless. For this and other reasons the precipitation must be conducted in some material that will avoid these difficulties.

The material commonly employed is gelatin, a substance analogous to glue in composition and like glue in that it is extracted from the bones and hides of cattle. The gelatin is dissolved in water and the bromide and iodide solutions are carefully mixed with it. To this mixture, heated to the correct temperature, is added the silver nitrate solution. The precipitate of the sensitive silver salts is held in suspension by the gelatin.

All emulsion-making operations are conducted in rooms lighted with safelights. The actual operations of making the emulsion are conducted in silver-lined, steam-jacketed vessels, provided with agitators. Soluble salts formed during the reaction—in contrast to the insoluble silver bromide and silver iodide salts—must be washed out of the solution. This is accomplished by chilling it to a jelly, then straining it by pressing the mass through a chamber with a perforated bottom and sides, and washing the spaghetti-like strands many times in cold water. The shredded emulsion is then melted and coated on the film base.

Again, in this process, thickness is an important factor. Consequently, the machine used for emulsion coating is very delicate. After the film has been coated it is carried in large loops through chilling rooms to set and harden—in other words, to become conditioned. When it is thoroughly dry, motion picture film is automatically cut into strips 1⅜ inches wide (a little less than half that width in the case of amateur motion picture film), and is wound in rolls varying from 50 to 1,000 feet in length.

The final operation is perforating, where the greatest care is taken to insure accuracy so that the film shall run smoothly through cameras, printers, or projectors, as the case may be, which determines the steadiness of the pictures on the screen. Even such an apparently small detail as the shape of the perforations has been minutely studied.

That fact is only typical of the painstaking yet imaginative effort that has gone into film-making and will probably go into the making of film to meet whatever new needs cinematography brings forth.

OPTICAL SCIENCE IN CINEMATOGRAPHY BIBLIOGRAPHY

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STRONG is the temptation for the specialist in any field, when given the chance, to claim for his specialty credit for any and all developments since the creation. Such an impulse arises in meditating upon the contributions of optics to cinematography for the thought immediately occurs that without optics there could be no cinematography. Second thought, however, reveals how idle and superficial this impulse is for it is equally true that without the chemist there could be no cinematography and a little further reflection brings to light the fact that the optical engineer and the chemist must admit to an equal share in the credit a third collaborator, the precision mechanic who has contributed that incredible mechanism, the high grade motion picture camera.

Three tools are absolutely necessary to the making of even the shortest and simplest motion picture, viz. lens, camera, and film. Lenses competent to take pictures were available long before cinematography was born. A flexible base to support a photographic emulsion appeared in 1888 and with lenses and film available it was not long before useable cameras were designed and cinematography became practicable. In the early period of its development, the art accepted without question the existing lenses and photographic emulsions which had been designed to meet the requirements of still photography, for both had reached a higher state of development than the cameras and the technique of the camera operators. As cameras were perfected and cinematographers began to see the artistic possibilities of the new medium of expression it began to be apparent that here were conditions which were different from still photography and not only were different lenses and different film required but the optical engineer was asked to cooperate with the electrical engineer in illuminating the sets. It is since that period that optics has made its principal intentional contributions to cinematography.

These contributions consist for the most part of devices for providing illumination adequate in volume and of suitable character, of high speed photographic lenses, and of a few specialties such as the optical devices required in natural color cinematography and some special process effects; not to mention stereoscopic motion pictures, etc., the class in which the would-be inventor delights to exercise his imagination. There is always the hope that the motion picture industry can be induced to part with a million dollars for one of their ingenious devices and a sublime confidence that the optical engineer can really make it work.

To catalog all of the optical elements and devices used in all branches and phases of cinematography would be tedious and un-

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profitable. This article will be limited, therefore, to a consideration of some aspects of the illumination problem and to some interesting phases in the history of the development of photographic lenses.

The most interesting optical unit in illuminating equipment is the parabolic mirror. Why is a mirror used at all and why is it para-

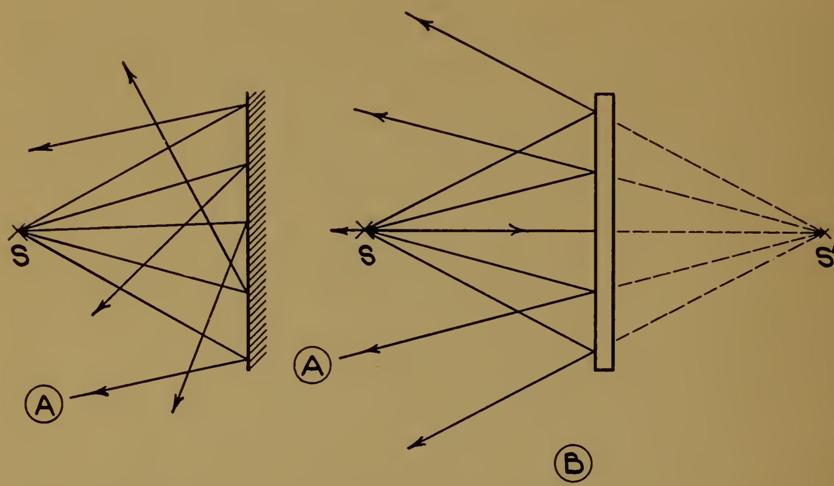


Fig. 1a—(Left) Diffuse reflection from a magnesium carbonate block.
Fig. 1 b—(Right) Specular reflection from a plane mirror.

bolic? The first may seem like a silly question to which the answer is obvious but the following discussion of its performance may present some new points of view, at least, to some of the readers of this article. If we assume any small source of light such, for example, as a 6 V automobile headlight bulb placed in the middle of a room it radiates light in all directions. The distribution will not be absolutely uniform because parts of the filament intercept light from other parts and the base of the lamp will cast a shadow but except for the region under the base of the lamp all portions of the room will receive direct light. If we now place a blackened screen on one side of the lamp it will intercept part of the radiation and cast a shadow. The intercepted radiation is lost. It is absorbed by the black pigment and its energy used up in raising the temperature of the screen; the light has been transformed into heat. If we substitute a white screen, the illumination of the area of the room in front of the screen will be increased while the region back of the screen is dark. If the white screen is a perfect reflector no light will be lost; it is simply directed to a different part of the room.

A block of magnesium carbonate is a nearly perfect reflector, so is also a silvered plane glass mirror. They are greatly different in their behavior, however, for the first is practically a perfect diffuse reflector and the second a nearly perfect specular reflector. The difference in their behavior is indicated in Fig. 1a and 1b. In Fig. 1a a number of rays of light are shown emanating from the light source and falling on the block of magnesium carbonate whereupon they are reflected in a perfectly erratic manner. In Fig. 1b the rays leaving the source fall on the surface of the silvered mirror and are reflected in a perfectly correlated manner and in fact in such a way that they appear to emerge from point S^1 back of the mirror and at the same distance from it as the light point is in front of it. S^1 is an image of S formed by the mirror. An observer standing at position A in Fig. 1a will see the whole block of magnesium carbonate illuminated by the single point source of light so long as A is in front of the reflecting surface but an observer standing at a corresponding point A in Fig. 1b will

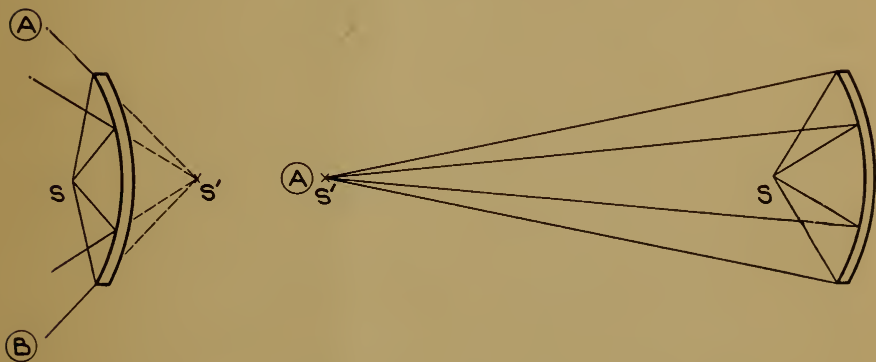


Fig. 2a—(Left) Reflection from concave mirror close to source.

Fig. 2b—(Right) Reflection from concave mirror separated from the source by a distance slightly greater than the focal length.

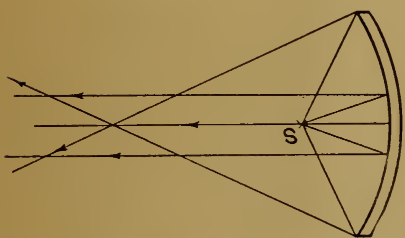
see nothing of the surface of the mirror but will see an apparent second source of light at S^1. No matter where the observer takes his position in Fig. 1a as long as he is in front of the magnesium carbonate block he will see it illuminated and his eye will receive illumination from it but in Fig. 1b if the observer moves to position B he will not be able to see the reflected image of S and his eye will receive no light from the mirror. Within a certain region then it is obvious that the mirror contributes light but that region is definitely limited. Within the region in which it is effective it is exactly as if there were two sources of light, S and S^1, instead of one. This is intended to be taken literally. If the mirror is taken away and a new source equal in intensity to S be placed at S^1 the effect at point A will be identical with the effect prevailing when we had the one source and the mirror.

Suppose now we replace the plano mirror with a concave spherical mirror of any available radiums of curvature placing the mirror fairly close to the lamp in the manner indicated in Fig. 2a. Just as in the case of the plano mirror an observer standing in front of this set-up will see an image of the source of light formed in the mirror as long as he stays within a region which depends, under the conditions of the set-up, on the diameter of the mirror and which is included within position A and B in the figure. If the concave mirror is of the same diameter as the plano mirror of Fig 1b and at the same distance from the source of light, the image of the light source seen by looking into the mirror will be larger than the image formed in the plano mirror and, in the same proportion, the extent of the angle included between the position A and B will be less than in the case of the plano mirror. If the diameter of the concave mirror is the same as the diameter of the plain mirror and the plane of the front rim of the concave mirror is at the same distance from the light source as the plano mirror, they will both receive from the light source the same total amount of light. In the case of the concave mirror it is reflected into a space smaller than in the case of the plano mirror. The same amount of light concentrated in smaller space obviously means a higher concentration of light.

This phenomenon can readily be studied if the observer takes his position at some such point as A in Fig. 2b and has an assistant move the concave mirror back away from the source of light. He will observe that the size of the reflected image constantly increases, until the point is reached indicated in Fig. 2b in which the reflected image appears to fill the entire area of the mirror. If the observer will hold up a piece of white cardboard from time to time as the image S^1 in the mirror grows larger he will find that the illumination of the card is constantly increasing. If, under the conditions of Fig. 2b, the observer now attempts lateral excursions to the right and left, he will find that the region within which the image is visible in the mirror is very much restricted, but on the other hand he will find with his white card that the concentration of light within the area through which such a reflected image is visible is very much higher than it was at any time before. He will find in fact that the source of light is now imaged by the mirror on the card if the latter is held at the point from which the mirror appears filled with light. This simple experiment which can be carried out by anyone with very modest equipment leads to an interesting conclusion; namely, that as the size of the image formed by the mirror increases, the concentration of light within the area illuminated by it increases in proportion.

In fact, it can be said that the purpose of introducing a mirror adjusted as in Fig. 2b is, in effect, to substitute for the original source, another source just as bright as the original but as large as the mirror which is used and the illumination contributed at A by the mirror is as much larger than that contributed by the original source as the area of the mirror exceeds the area of the original source of light. It is obvious that the total radiation falling on A in Fig. 2b consists of two parts, first, some direct radiation from the source of light, and second, radiation which arising in the source of light originally is reflected to the point A by the mirror. If we interpose in front of the light source a small opaque screen, we will find the total illumination on the card is scarcely affected; in other words, the direct radiation from the lamp is very much less now than the reflected radiation from the mirror. If we have a source of light whose area is, let us say, one half inch in diameter and place back of this source a mirror 36 inches in diameter and adjust its position until the source of light is imaged on a screen, the illumination contributed by the mirror will be in the neighborhood of 5200 times as bright as the illumination contributed directly by the source, since the area of the mirror is approximately 5200 times as large as the source.

An interesting confirmation of the relations between illumination and the size of the image formed by the mirror can be observed in any ordinary mirror spotlight. It is common observation that when such a unit is adjusted to give a flood lighting effect by shifting the lamp closer to the mirror, the margin of the illuminated area shows a bright ring and the center is relatively darker than the margin. If an observer having armed himself with a sufficiently dense filter to protect his eyes or else reduces the illumination by introducing resistance to the point where the source of light is simply red hot, and then



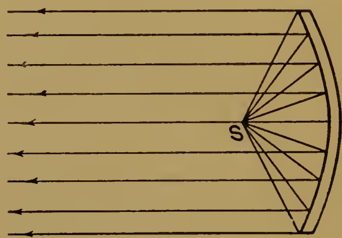


Fig. 3a—(Left) Spherical mirror with source in the principal focus showing spherical aberration of the marginal rays.

Fig. 3b—(Right) Parabolic mirror with source in the principal focus producing a parallel beam of light.

walks across the illuminated area looking into the mirror, he will observe that the size of the reflected image, which no longer fills the whole mirror, moves across the face of the mirror and becomes larger as he reaches the edge of the illuminated area and the reflected image moves into the marginal zone of the mirror. Greater brightness is here directly associated with increased size of reflected image establishing a direct connection between the two.

We have in this way attempted to frame an answer to the question why the mirror is used. The answer to the question why a parabolic mirror is used instead of a spherical mirror is very simple. Referring back to Fig. 1b, it is seen that all the rays of light reflected on the mirror appear to come from a single point S^1, the image of the source S. This represents the true state of affairs without reservations or qualifications. Unfortunately, the plain mirror is the only perfect optical instrument. It is unfortunate for optical designers that its applications are so limited. When we come to a concave spherical mirror, quite different conditions prevail. We fail to find this well-behaved correlation between the reflecting rays, but on the other hand find the conditions such as shown in Fig. 3a. Here the source of light is shown located in the principal focus of the mirror. It is, therefore, imaged at infinity, or in other words, the mirror is supposed to produce a parallel beam of light. Only the very center part of the mirror, however, is capable of performing in this way. As indicated in the picture the deviation of the rays striking the marginal zone of the mirror is too great so that they cross ahead of the light source and give rise after they cross to a diverging beam. From the standpoint of geometrical optics, the curvature of the spherical mirror is too great as we go from the center toward the margin. What is needed in order to cause the marginal rays to become parallel with the axial or central rays is a mirror whose curvature decreases from the center toward the margin. Exactly the required decrease of curvature is provided by the parabola. Any ray emanating from a point source of light placed in the focus of a parabolic mirror is reflected by the mirror parallel to its axis as shown in Fig. 3b. In other words, a point source of light placed in the focus of such a mirror gives rise to an absolutely parallel beam of light.

Lest the use of the expression "parallel beam of light" in one of two places lead anyone to erroneous conclusions; it should be said right away that such a thing as a parallel beam of light cannot exist. In fact, the only possible way in which a parallel beam of light could be obtained would be with the use of a point source of light which is an impossibility. In order for a source of light to give any light, whatever, it must have finite dimensions. If the source of light has finite dimensions, the minimum angle of divergence of the beam of light can never be less than the angle subtended by the source of light at the mirror or lens employed with it.

In addition to mirror spots condenser spots are also employed. The theory involved is identical. If a condenser spot light is adjusted to give the smallest and brightest spot of light, an observer taking his position in the center of this spot and looking at the condenser lens will see that it is entirely filled with light or, in other words, the purpose of a condenser is to replace the original source of light by another source equally bright but much larger in diameter and, therefore, capable of giving us a correspondingly increased amount of illumination. The other lighting units have practically nothing of interest from a standpoint of optics involved in them, therefore, we will pay no further attention to them. For one, who may desire to read further in the subject of the behavior of mirrors and who is able to read German, two excellent and interesting little books are mentioned at the end of this article. The second is a translation into German of the work of Mangin and Tschikolew, French and Russian military officers respectively who were interested in the performance of concave mirrors for military signal purposes.

We now come to that most interesting of optical implements, the photographic lens. When photography was born, the only lenses available were single achromatic meniscus lenses, very low in speed and very limited as to the size of the field of view they would cover with satisfactory definition. These slow lenses combined with the very slow emulsions available at the time made photography almost hopeless.

In 1841 Joseph Petzval accomplished at one stroke an enormous advance in the speed of lenses. Within a few years, other people improved on his design in point of speed and succeeded in obtaining lenses with small covering power to be sure but whose speed was as fast as anything which has been designed since that time until very recently. This lens, however, was characterized by a very small field of critical definition which, while entirely satisfactory for portrait photography, was quite unsatisfactory for other kinds of work and for many years the aim of the photographic lens designer was to improve lenses in respect to the size of the field which they would cover with sharp definition.

Petzval's contribution consisted not only in making a very useful lens available but also in pointing the way to future progress. His researches inspired other mathematicians to take up the problem of analyzing the aberrations of a lens and of finding means to correct them.

Since no discussion of photographic lenses can proceed far without employing references to the various aberrations which characterize the performance of simple lenses and which must be corrected in the photographic lens, and since space forbids entering into a discussion of the nature of aberrations within this article, references will be given at the end of the article to books in which a full discussion of the subject may be found.

The elements at the disposal of a lens designer are the number and shape of the individual components of the lens, the magnitude of the separations between the components and the kinds of glass employed. The construction employed by Petzval is shown in Fig. 4. About 1866, Steinheil introduced the idea of a symmetrical lens, one whose

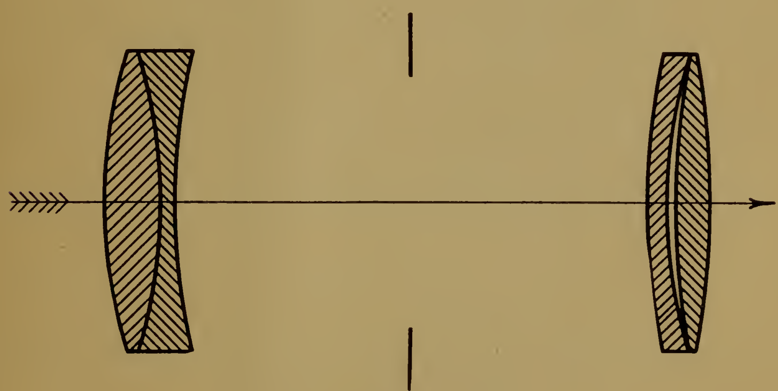


Fig. 4—Petzval's Portrait Lens.

front and back components were symmetrical with respect to a diaphragm lying midway between them. The use of the symmetrical type of construction represented by the Steinheil "aplanat" ensures without any further effort a hightly satisfactory correction of two of the aberrations, namely, coma and distortion. This type of lens enjoyed a great vogue as the R. R. or Rapid Rectilinear. It could be carried to a speed of f:8.0 and cover moderate fields with a creditable quality of image. The general appearance is shown in Fig. 5.

Steinheil also discovered another principle of very great value in the design of photographic lenses; namely, the practice of introducing into one component a large overcorrection of some aberrations and compensating them by suitable amounts of undercorrection in the other component with the advantage that he thereby reduced the uncorrectable residual amount of aberrations which must always exist in any lens. This principle was enunciated in U. S. Patent No. 241438, granted to Steinheil on May 10, 1881.

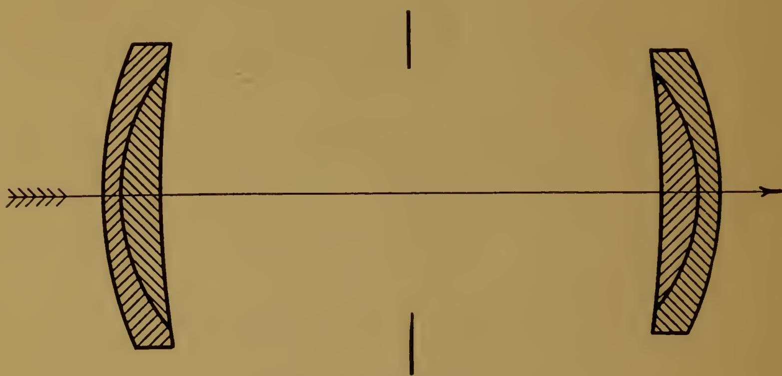


Fig. 5—Steinheil's Aplanat (Rapid Rectilinear)

All of these lenses, however, exhibited astigmatism, curvature of field or both, generally both. The first objective to be simultaneously corrected for astigmatism and curvature of field is described in U. S. Patent No. 444714, granted to Dr. Rudolph on January 13, 1891. This achievement was made possible by the perfection of types of glass which were not available to the earlier designers. One of the constructions described in this patent reached the very respectable speed of f:6.0. Other examples, however, were low speed lenses.

A period of intense activity in photographic lens design followed the invention by Rudolph and many different forms of lenses were proposed, some symmetrical and some unsymmetrical. In 1895, Harold Dennis Taylor, in U. S. Patent No. 540122, described a lens corrected for all the ordinary operations and composed of but three elements, two collective lenses and one dispersive lens mounted between them, separated by air spaces. This form which has become widely known as the Cooke Triplet is shown in Fig. 6. In 1903, U. S. Patent No. 72140 was granted to Dr. Rudolph covering the construction which has become world famous under the name Tessar. (Illustrated in Fig. 7). This lens forms an image of excellent quality over a field of 50° to 60° at a speed of f:4.5 which is fast enough for the needs of hand cameras and most other ordinary applications of photography. This construction was later carried to a speed of f:3.5 in lenses of shorter focal length, and this for several years represented the highest available speed in a lens corrected for astigmatism and curvature of field and for many years this was regarded as adequate for motion picture photography.

The first attempts to make a serious advance in the speed of lenses seems to have been made by C. C. Minor; in 1913 he was granted

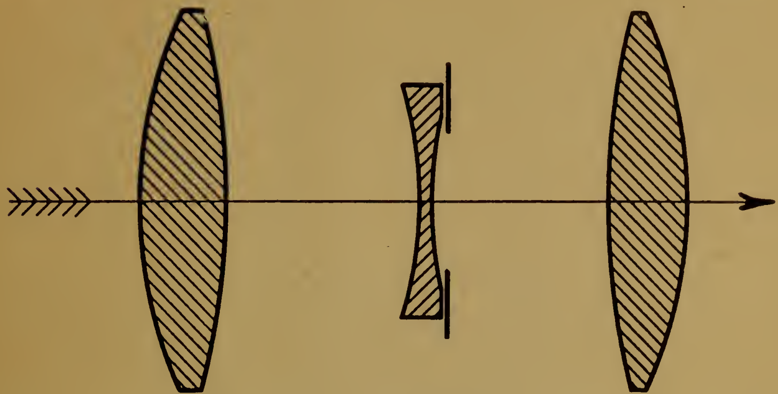


Fig. 6—Cooke Triplet.

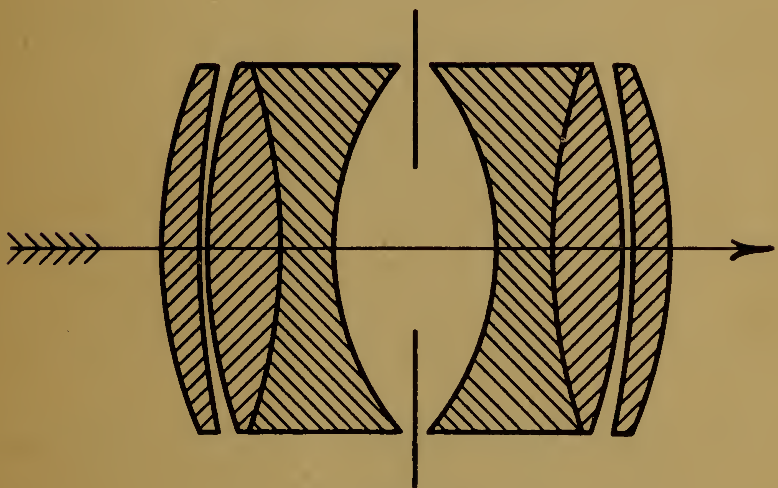


Fig. 7—Zeiss Tessar.

U. S. Patent No. 1077420, in which he went so far as to describe a construction for a lens whose aperture was twice as great as its focal lengths corresponding to its speed f:0.5. These lenses seem to have been constructed on no theoretical principles but appear to have been assembled by adding one lens after another until some kind of result was achieved.

The demand for faster lenses seems to have been stimulated, however, by the attempts to create them and in a few more years they began to appear from several sources. It will be impossible to deal with all of them but conforming to the general plan of this article we will confine ourselves to a consideration of some of the general lines of attack.

One of these consisted in increasing the speed of existing forms of lenses. To the uninitiated this might appear to be simply a matter of making the lenses larger in diameter but the problem is far from being so simple. If we attempt to apply this practice to any well known construction it is usually necessary to increase the thickness of the lenses and the effect of the increased diameter and increased glass thickness is to ruin the performance of the lens. It is necessary then to recorrect for practically all the aberrations. This may be possible or it may not, but in any event there is certain to be an increase in the uncorrectable residual aberration. To make this a little clearer let us consider briefly the question of spherical aberration. It is generally fairly easy to unite in a common focus rays of light of any one color passing through the center of the lens and through some other zone, say the margin. This accomplished, however, rays from the same object passing through other zones of the lens generally fail to unite in that same focal point and if this zonal effect is too great the image will be useless. This effect exists not only in spherical aberration but in the other aberrations which concern more particularly the quality of the image at the margin of the picture. The attempt to secure higher speed lenses, therefore, by the simple practice of making the lenses larger in diameter fails because of the aberrations of intermediate zones. Some of the old standard types of lenses, however, were found to possess capabilities of expansion in speed in the short focal lengths employed in motion picture work. The first of these, and, in fact, the first lens of speed faster than f:3.5 to find favor in this field was the Bausch and Lomb Ultra Rapid Anastigmat. This lens, introduced in 1922, was a development of the triplet carried to a speed of f:2.7. This not only represented an increase of 70% in speed but had a quality of image unusually satisfactory for cinematography. Another example is the Zeiss f:2.7 Tessar in which the general type of the Tessar was found, for short focal lengths, to permit opening up to f:2.7 from the previous maximum of f:3.5.

Without attempting to exhaust the list of such cases let us return to 1920 to examine another method of attack. In this year, Minor was granted U. S. Patent No. 1,360,667 in which there was described a lense with a speed somewhat greater than f:2.0 constructed on a very simple principle. If a simple Cooke triplet is opened up to f:2.0 it is found that the uncorrectable spherical zones are too great to make a useful lens but Minor found that by dividing the work of the first crown elements between the two lenses the total power of which was equal to the power of the original element, the amount of spherical aberration set up by this compound lens in spite of its larger diameter was not too great to be corrected by the following concave lens, and at the same time maintain a fairly reasonable correction of the intermediate zones between the margin and the axis. This is the essential philosophy of the lens. The principle was then applied by many other lens designers since that time, and possibly every conceivable modification in which each and every one of the elements has been made compound has been proposed and patented. Minor's lens is shown in Fig. 8.

In 1925 U. S. Patent No. 1540752 was granted to W. F. Bielicke in which the other obvious possibility of arriving at the same result was described. This consists in splitting the rear element of a Cooke Triplet in two parts as shown in Fig. 9, thereby reducing the spherical aberration due to the crown elements which must be con-

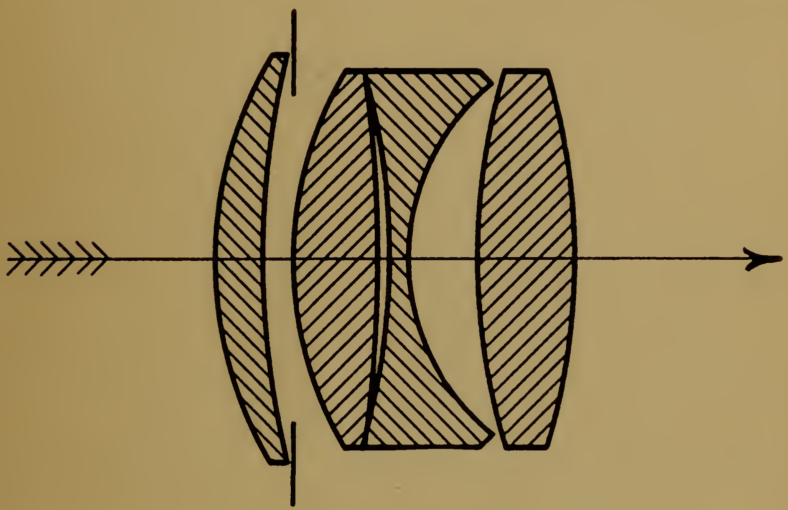


Fig. 8—Minor's f:1.7 lens of 1920.

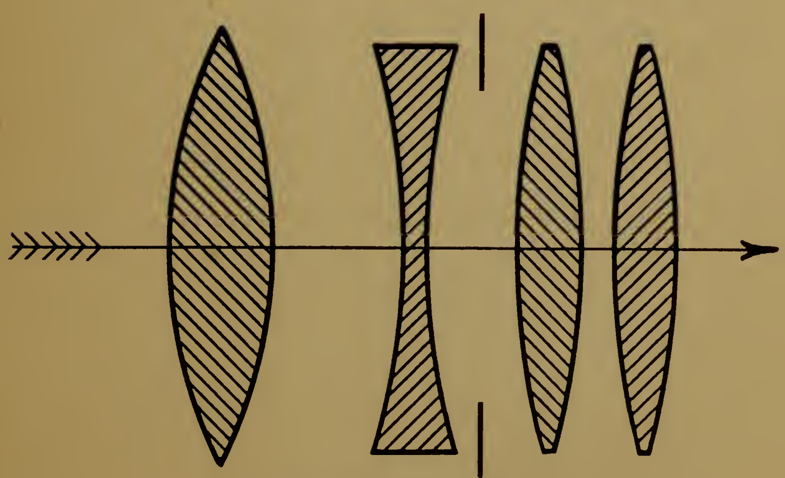


Fig. 9—Tachar f:1.8 and f:2.3.

templated by the single negative. By this he also reached a speed of approximately f:2.0 with a satisfactory quality of definition for short focus lenses. This expedient has also been developed by other designers adding to the complication and with some increase of speed. Bielicke's is sold under the trade name of Astro Tachar in speeds of f:1.8 and f:2.3.

The second general method of attack may therefore be said to consist in splitting either the front or the back element of a Cooke

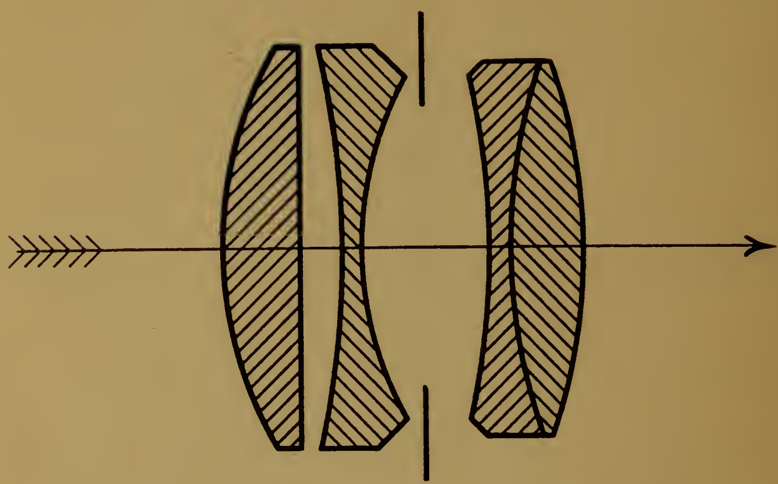


Fig. 10—Rudolph's Double Gauss Lens of 1897.

triplet into two parts and then elaborating much or little, according to the degree of refinement it is regarded as desirable to reach in correcting aberrations.

There is a third general type of lens which permits the attainment of high speed and which has a long and interesting history. It goes back to a form of telescope objective proposed by Gauss which consisted of two meniscus lenses and which was characterized by the fact that chromatic aberration was corrected for two zones (say the marginal and the axial zone) instead of one as in the ordinary lens. In 1889 Alvan G. Clark, of Cambridgeport, Massachusetts, described a photographic lens whose front and back component were each of the form of a Gauss telescope objective. This lens had many excellent features, but it was not corrected for astigmatism. In 1897 the United States Patent Office granted a patent No. 583336 to Dr. Rudolph on a photographic objective consisting of two Gauss telescope objectives of which the concave member in the one case and the convex number in another case were made compound, and in which he made use of the new kind of glass available to the end that he finally succeeded in correcting astigmatism and curvature of field. With this construction he reached a speed of f:4.0. The form which appears to have been most successful is shown in Fig. 10.

Rudolph's lens, however, was symmetrical and while coma causes no trouble in symmetrical lenses of low or moderate aperture it does become troublesome in lenses of high speed. No further advance of this type of lens is noted until in 1920, British patent No. 157,040 was granted to Taylor, Taylor and Hobson on a lens later described in detail by H. W. Lee in the Transactions of the Optical Society XXV, 5, Page 240-248. This lens, which has a speed of f:2.0, takes off from the Rudolph lens of 1897, improving upon it by increasing its speed four fold while maintaining good correction by departing somewhat from the symmetrical form and employing different glasses. This lens has also achieved popularity in motion picture photography.

The same principle has been followed in the design of the Bausch & Lomb Raytar lens which employs still different glass combinations in the interest of still better correction of coma. This lens has been designed to work at f:2.3 although higher speeds are easily attainable. This is a 1928-29 product on which production has not reached sufficient volume at the time this is written to justify announcing it.

That the construction does permit greater speeds is proved by the fact that Zeiss has apparently been able to secure good image quality in a lens of f:1.4. This is gathered from the provisional patent specifications abstracted in the Official Journal of the British Patent Office of November 21, 1928, in which a lens of this speed is described and shown to follow in the direct line of succession from the original double Gauss objective.

It would be beyond the limits set for this article to even mention all the attempts which have been made in the last ten years to produce faster lenses for motion picture photography so it has been regarded as more interesting and profitable to discuss the principles of lens construction along which useful advances have been made.

In all the efforts to improve lenses and to produce faster lenses, no fundamentally new principles have been discovered since the invention of the anastigmat. Faster lenses have been achieved with the aid of old principles of design and have been realized partly due to the fact that they are required only in comparatively short focal lengths.

With regard to future developments, there seems little hope of any further marked increase in speed. A limit is set by two considerations. In the first place we are limited by the necessity for some depth of focus. As the speed increases depth of focus decreases for conditions otherwise the same, and we soon reach a point where the depth of focus becomes too shallow for any purpose other than copying. Then, too, a limit is imposed by something like the economic law of diminishing returns. When we get into this region of ultra fast lenses exposure time is not found to decrease in proportion to the increase in speed of lens because of relatively greater losses of light within the lens itself. Light is lost at each boundary surface separating air from glass and is absorbed by the glass itself. The more complex the construction, and complexity is demanded in securing good image quality combined with high speed, the greater is the loss of light due to reflection and absorption. Unless new materials become available which enables equally good results to be obtained with simpler constructions, this consideration very effectively sets a limit to the useful speed of a lens. Altogether there is little reason to expect useful lenses of higher speeds than are now available in the range of focal lengths now employed.

The optical systems involved in color photography are interesting but it is felt that to include any adequate survey of them would extend this article beyond reasonable limits. The late Professor E. J. Wall has collected practically all such information into his book on Color Photography to which the reader is referred. He has also devoted his time in serious fashion to compiling an analysis of the various proposals within the field of stereoscopic motion pictures, a field regarded as hopeless by the optical engineer but glittering with promise for the amateur.

A short list of references is appended for the sake of those who might wish to consult them.

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THE EVOLUTION OF THE MOTION PICTURE PROFESSIONAL CAMERA

*Joseph A. Dubray**

SINCE the time when researchers discovered the means by which the analysis and synthesis of movements were made possible through the agency of photography, the motion picture camera has undergone a series of improvements, many of which may be classed as inventions in the proper sense of the word.

Much has been written of the early experiments made by a handful of inventors and their efforts to apply scientifically sound principles to the insufficient means they had at their disposal for the practical realization of the photographic analysis and synthesis of motion.

These experiments involved at first the use of glass plates or paper ribbons coated with photographic emulsions of slow speed. They involved the viewing of the pictures thus obtained through peep-hole apparatus or through crude contrivances which permitted only one or very few persons to view them.

These crude apparatus and insufficient results were, however, the forerunners of the motion pictures of today.

Rapid photographic emulsions and the use of celluloid for their support marked two steps which laid the foundation to the new art.

The sensitiveness of the emulsion permitted the taking of instantaneous exposure while the transparency, flexibility and lightness of celluloid permitted the preparation of rolls of film of sufficient length to allow the taking of numerous pictures in rapid succession with less encumbrance of weight and unwieldy mass.

Once these essentials became available, the motion picture camera was devised upon principles which, on the main, remain unaltered to this day.

Motion Picture photography varies from Still Picture photography in that a considerable number of images of the same subject are taken instead of a single one.

These photographic records are taken in rapid succession in order to answer the conditions imposed by the phenomenon of persistence of vision upon which the whole structure of motion pictures is based.

The series of photographic images which comprise a motion picture film require, of necessity, the most accurate registration of the film at the aperture of the camera, so that when projected with considerable magnification, they will perfectly superpose each other on the screen.

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These essentials called for the development of an apparatus which would be similar to a still photographic camera but which would be capable of intermittently carrying the film, at the focal plane of the lens, so that an unexposed portion of the film would replace an already exposed portion at the aperture of the instrument and remain there perfectly stationary for a sufficient time for exposure.

Fig. 1

An example of Muybridge's photographic analysis of motion. Twelve cameras were used, the shutters of which were automatically made to function at the proper moment by the subject itself.

The essential features of a motion picture camera, exception made of the photographic objective, are:

First: A mechanism which intermittently brings to its proper position at the photographic aperture of the apparatus a portion of the light sensitive film.

Second: A shutter which intermittently intercepts the light transmitted by the lens during the periods the film is in motion.

Third: Light proof receptacles in which the unexposed and the exposed film can be stored.

Other appliances, such as the tripod, and the number of attachments and devices which complete a motion picture camera, are only commodities which, although indispensable in modern motion picture making, have no bearing with the fundamental operating principles of the instrument.

The requisite of film intermittent motion presented the problem of designing a mechanism that would permit the alternation of periods of rest with periods of motion many times during a fleeting second.

The knowledge of the phenomenon of persistance of vision gave the point of departure to the first designers of the motion picture camera. Calculation and experimentation proved that some fifty occultations per second of a sufficiently brilliant source of light would not destroy the impression of continuous illumination of a screen upon which the light was projected.

In accordance with this established fact, it would have been necessary to photograph fifty pictures of a moving object each second, and to project them at the same speed at which they were taken.

This, however, involved serious difficulties because of the extremely high speed at which the intermittent movement would have to function and because of the shortness of the exposure time thus available. Inordinate consumption of film was also to be considered with a view to the economic factor involved and the bulk and weight of the film which would have been necessary for a picture of even a short duration. This problem was solved by reducing the number of pictures to be taken in a second to one-third of fifty or, to be more exact, sixteen per second, and to maintain the film stationary in the projecting machine during three periods of the projector's shutter movement. The condition of fifty occultations per second was thus realized for the synthesis of motion, while simplifying the problems involved in its analysis, and maintaining intact the synchronization of movement between the subject and the projected image.

The problems inherent to the intermittent motion of the film in the camera were nevertheless quite difficult to solve in consideration of the necessity of perfect registration and of the ease with which the photographic emulsion can be marred when submitted to friction.

In order to intermittently and positively move the film for an exact distance in its alloted path, Edison in his "Kinetoscope" and Lumiere in his "Cinematographe", conceived the idea of perforating the edges of the film and designing a mechanism which would be supplied either with a sprocket intermittently rotated by a Geneva movement (mostly used in projection machines), or with two metallic teeth or fingers (for the camera) driven by the action of cams in such manner that they would alternately engage into and disengage from the perforations after completing a stroke corresponding to the length of film to be displaced.

The Edison perforations were rectangular in shape and their number was four for each length of displacement of film. The Lumiere perforations were round and at a distance from each other equal to the length of displacement of film.

There is little doubt that Lumiere, and perhaps Edison, were guided in the adoption of the film perforations by the successful operation of a similar system used in the Jacquard weaving loom. In this, an endless band of perforated paper was used to select the "simples" for each rising and lowering of the warp threads.

No matter what prompted the use of film perforations, this proved to be the most practical means of film control, and it could not be superseded by serious attempts of devising other systems, the most noteworthy of which was, perhaps, the Demeny cam and beater mechanism. This mechanism enjoyed very little success in spite of the perseverance displayed by the constructor, Gaumont, in his attempts to perfect it.

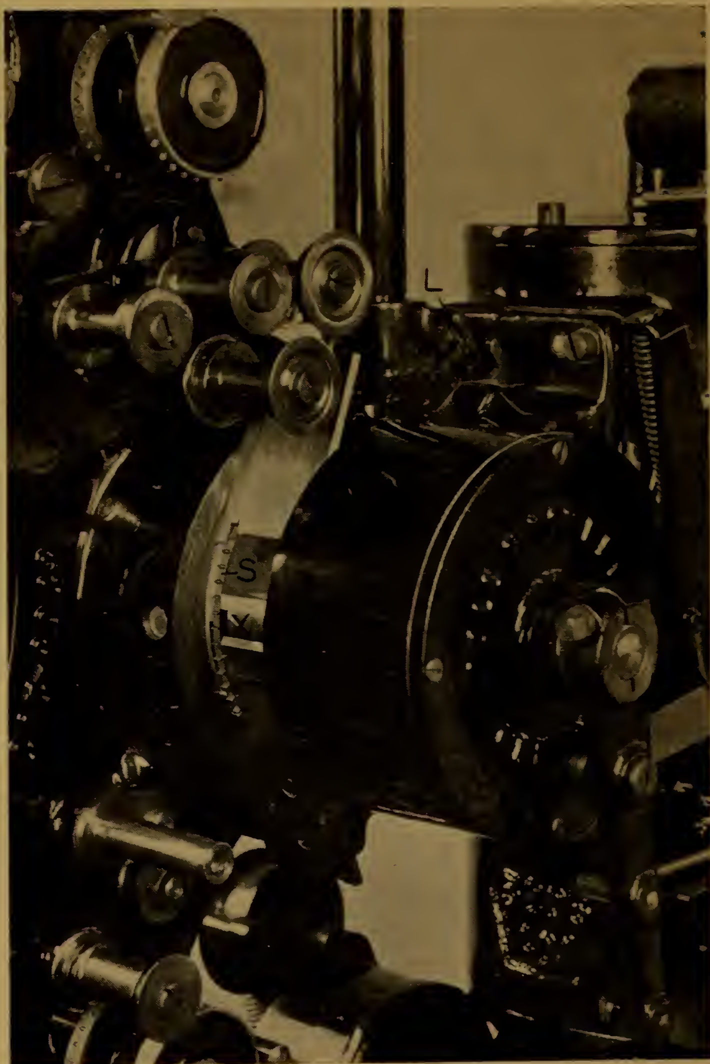

Fig. 2

Bell & Howell Continuous Printer. Printer head and film control mechanism with gate removed to show sound and picture triple shutter attachment. S—Main film control sprocket. X—Printing aperture with shutter set for printing sound track. L—Shutter control levers. The diameter of the main control sprocket is calculated to compensate for shrinkage of negative film in processing. The sprocket teeth are designed with a view to marginal control of shrinkage.

The shrinkage characteristic of the film, which is the term used to define the alteration in length and width to which the film is subject during its laboratory processing, brought forth the necessity of painstaking investigation before the shape, size and pitch of its perforations could be standardized.

Shrinkage, incidentally, necessitated the development of perforating machines of extreme precision of operation; and that of sprockets for cameras, printers and projectors in which the shape, size and pitch of the teeth were carefully calculated.

It is noteworthy to mention that the European method of counteracting the ill effects of film shrinkage consisted in the establishment of two dimensions of film perforations: one for unprocessed negative film, and one for positive film, in order that the latter would coincide with the reduced dimensions assumed by the negative film after processing.

American ingenuity, however, could dispense with this rather bothersome method. A. S. Howell lead the way by designing the mechanism of the printing machine in such manner that a compensation for the differences in dimension between processed negative and unprocessed positive films was obtained automatically and with greater accuracy than was possible through the use of two perforations of different size.

The shape of the perforation for negative film was officially standardized by the Society of Motion Picture Engineers after the Bell & Howell Company of Chicago had produced the perforating machine

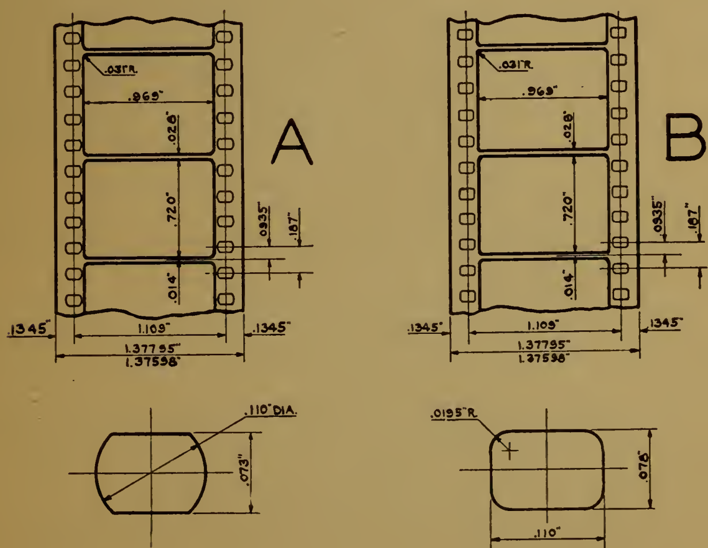

Fig. 3

Standard dimensions of 35mm. film. A—Bell & Howell negative perforation. B—Rectangular positive perforation. Below, enlarged view of shape and dimensions of both perforations.

which is now almost universally used in America and which has been accepted by most of the motion picture film manufacturers throughout the world.

The shape, dimensions, and pitch of the Bell & Howell perforation are illustrated in Figure 3 at A, while at B in the same figure is shown the rectangular perforation with rounded corners used for positive film. (The pitch is the distance between the centers of adjoining perforations.)

There is little doubt that if a change of dimensions of the film, which will undoubtedly take place, due to the favor which a wider film is gaining at the present writing, should be decided upon, the rectangular perforation with rounded corners would be chosen as standard for both negative and positive films, because of the greater possibility it presents for film registration, especially in the printing and the projection processes.

An interesting phase of the evolution of the motion picture camera is to be found in the standardization of the position of what is known as the "frame line", which is the space between two consecutive picture frames.

Here again, a perhaps less evident, but nevertheless quite sensible differentiation can be made between European and American procedure.

European manufacturers, mostly French, placed the frame division to align with the center of the perforations, while Americans placed it at mid-distance between two perforations.

This brought forth a very wearisome situation, inasmuch as during projection, the operator would have to watch the screen constantly and carefully to "frame" the different scenes of the same picture which happened to be taken with cameras of different frame line.

The writer well remembers the time in which he had to devise a camera framing device and have it installed in all the cameras belonging to the producing company for which he was Director of Photography, in order to make possible the photographing of the "trick" scenes so in vogue at that time without confining any one cinematogapher to the use of any one special camera. (Production methods were quite different then than they are now!)

The placing of the frame line at mid-distance between perforations was finally decided upon as "standard" procedure, and is nowadays universally used.

The Camera Intermittent Mechanism

The function of the intermittent mechanism of a motion picture camera is to perform several times each second the following cycle of movements:

1. To engage the film feeding fingers in a pair of perforations.

2. To displace the fingers in a downward (or upward) stroke of the length corresponding to the sum of the pitch of four perforations.

3. To withdraw the fingers from the perforations.

4. To displace the fingers in a direction opposite to that of movement 2 in order to bring them in the position they occupied before starting movement 1.

The requirements of the multidirectional action of the film feeding fingers were from the early days secured by the use of cam mechanisms. The design and construction of these demanded the greatest care because of the necessity that the speed of the fingers at the start and end of each stroke be as great as possible and because care had to be taken that the withdrawing of the fingers from the perforation would not begin until the film was in an absolute state of rest, in order to avoid undue stress and consequent wear of the film perforations.

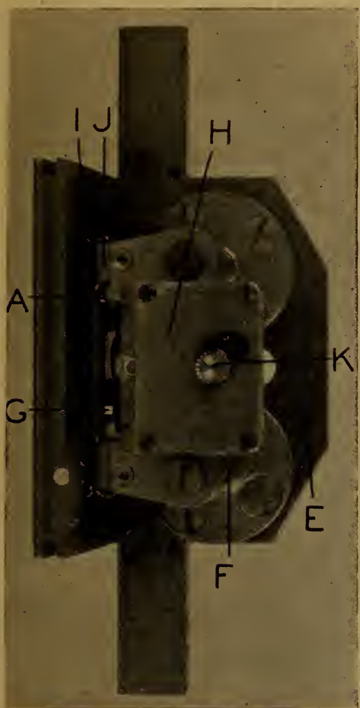

Fig. 4

Shuttle and leaves of Bell & Howell Intermittent Movement. A—Pilot Registering Pin. E.—Mounting Plate. F—Back Register Leaf Work Arm. G—Film Feeding Finger. H—Shuttle Guide Holder. I—Front Register Leaf. J—Back Register Leaf. K—Hand Operating Register Leaves Button. A clearance of less than .0005 inch is left between register leaves and either surface of film, in order to avoid friction upon the film surfaces. For inserting film between register leaves are disengaged from the pilot pins by moving button K.

Once the film was moved into its photographic position, it was found necessary to devise means by which it could be made to stabilize itself in perfect register at the camera aperture and remain in such exact position throughout the period of exposure.

In the early cameras, and in some cameras still manufactured today, this stabilizing effect is secured by holding the film laterally between two solid guide rails and by applying a pressure upon its back surface.

This method presents, however, some very serious inconveniences. Because of the friction generated between the film and the walls of the film channel in which it is running, there is constant danger through the almost unavoidable filtering of dust or dirt particles into the film channel and the producing of abrasion markings and scratches upon the film surface. There is also the danger of creating "static markings" which would often be present when the film is used under unfavorable temperature conditions.

The most ingenious method by which these serious evils were eliminated was originated in America by A. S. Howell, Chief Engineer of the Bell & Howell Company. He devised a cam actioned intermittent mechanism so designed that the moment in which the film begins its movement downward, or upward, as the case may be, all pressure upon its surface is removed and the film is allowed to run freely through its channel. Pressure is again applied as soon as the film is in its stationary position, while perfect registration is secured at this exact moment by a pair of closely fitting stationary registering fingers which engage into a pair of perforations.

From the early days of Cinematography, it has been possible to reduce the speed of the camera at will and according to the needs of the operator. We all remember the beautiful results obtained by Pathe Frères in their educational pictures showing the growth of plants, the budding and blooming of flowers. Each picture frame was taken at seconds or minutes and even at hours interval and the film projected at normal speed showed in a few seconds the work that nature took days to perform.

Stop motion photography and reduced speeds in the taking of the photograph record were also very extensively used in films for entertainment; and very few comedies were made in the early days which did not, at some time, take advantage of the comical effects that can be obtained through this simple medium.

But the need was also soon felt for a camera which would permit a more exact analysis of motion of subjects moving at a great rate of speed. This demanded the recording of a much greater number of picture frames per second than the normal of 16, so that when projected normally the speed of the subject would be reduced proportionally to the higher speed of recording.

This phase of motion pictures interested at first only the research laboratory, and France lead the way in this field. As early as 1910, at the Marey Institute of Paris, as many as 2000 pictures per second were obtained with a camera in which a continuous movement was imparted to the film and the effect of intermittence was obtained by rapidly extinguishing and exciting a source of light. To obtain this effect, rapidly succeeding electric sparks were used and their frequency was secured by means of a current interrupter synchronized with the film driving sprocket.

Pictures at such high frequency (as many as 25,000 pictures per second have been obtained in laboratory experiments) had very little use in commercial cinematography, but it was soon evident that high speed cinematography could be used to great advantage in miniature cinematography, that is to say, for scenes in which the speed of objects of natural size was to be brought into time with the ambient of reduced size in which those objects were moving.

M. Labrely, of France, to whom ultra speed cinematography is greatly indebted, designed a camera with an intermittent movement, which could, with relative ease, take as many as 100 to 150 pictures per second. This camera was used in the first *slow motion* pictures presented to audiences in public auditoriums by Pathe Frères. The same inventor later designed the Debrie super-speed camera, which is used extensively abroad.

At the same time, America was following the path of progress. Since space does not permit us to enter into details of the research work and the results obtained in ultra speed cinematography for use of research laboratories, we may mention that the first super-speed mechanism capable of taking as many as 200 pictures per second for

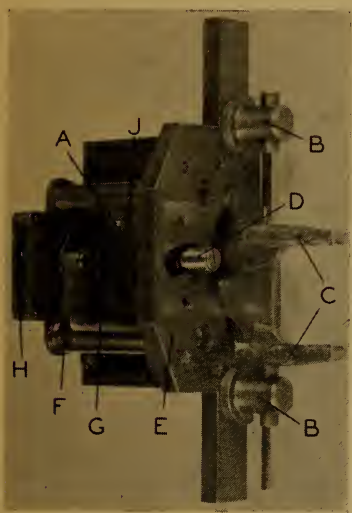

Fig. 5

Bell & Howell Registering Intermittent Mechanism. A—Pilot Registering Pins. B—Floating Shuttle Fork Bearings. C—Film Feeding Shuttle Fork Bearings. C—Film Feeding Shuttle Fork. D—Register Leaf Operating Cam Roller. E—Mounting Plate. F—Back Register Leaf Work Arm. G—Film Feeding Fingers. H—Shuttle Guide Holder. J—Back Register Leaf. The film is disengaged from the pilot registering pins at the moment that it starts its motion, through a backward motion of the register leaves controlled by cam action. The up and down motion of the shuttle is secured through the heart-shaped cam of the camera mechanism. Absolute register of each picture is assured by this mechanism

commercial work was devised in America by Mr. Howell, who, with a view to practical achievements, succeeded in making it part of the standard Bell & Howell camera, so that the same apparatus could be used for both ordinary and super-speed work.

The average rate of speed at which miniature scenes are taken is 128 frames per second, that is to say a speed eight times the normal speed. The considerable increase of the intermittent movement involved complex mechanical problems in consideration of the fact that none of the attributes of film safety and perfection of registration could be sacrificed.

Mr. Howell, in his super-speed mechanism, imparted the movement to the film by means of four pairs of pawls actioned by an eccentric driven by two gears, one of which is solidary part of the camera cam and gear shaft. The accuracy of film registration is secured by a pair of check-pawls which engage in a pair of perforations and stabilize the film at the end of each stroke of the pawls.

The lateral registration of the film is secured in this mechanism by a novel and carefully calculated "side tension" resulting from the action of a spring controlled floating rail upon one edge of the film, while the opposite edge is held in position by a stationary rail. This side tension system permits leaving a clearance between the film surfaces and the walls of the film channel. The elimination of friction

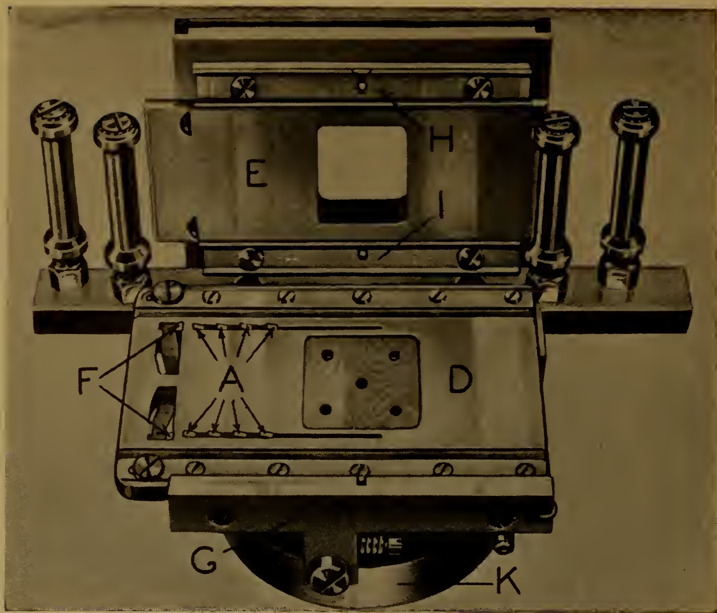

Fig. 6

Bell & Howell Super-speed Movement A—Film Feeding Fingers. D—Back Plate. E—Aperture Plate. F—Check Pawls. G—Side Tension Adjusting Bar. H—Floating Rail. I—Stationary Rail. K—Drive Gear Housing. This mechanism can be operated at as high a speed as 200 frames per second. The registering of the film is secured through the action of the check pawls. The side-tension system frees the film-surfaces from friction. When used for sound work, three pairs of feeding fingers are eliminated, and the steel driving gear replaced by a fibre one.

thus obtained reduces to a minimum the possibility of marring the film with abrasion markings or scratches.

The advent of sound pictures demanded that the motion picture camera should be silent in operation so that the mechanical noises resulting from the functioning of its rather complex parts would not be "picked up" by the sensitive microphone.

It is quite obvious that an intermittent movement, especially when working at the comparatively high speed of 24 pictures per second, which is the standard speed for pictures synchronized with sound, is likely to produce clicking noises. Sound pictures had such a meteoric success that mechanical engineers were caught almost unaware. The pressure of demand put them under the obligation of making the best out of an undesirable situation and of facing the new exigencies to the best of their ability. Fortunately, however, the precision of design and manufacture which had been reached prior to the coming of sound pictures made it possible to adapt the existing mechanisms to silent operation with considerable success. The super-speed movements were silenced to a considerable degree by changing the steel gears for fibre ones which eliminated the well known and peculiar noises produced by two metallic gears in contact. The fixed rate of speed of 24 pictures per second being far less than the speed the mechanism is capable of attaining, permitted furthermore the elimination of three out of the four pairs of pawls, which resulted in a great reduction of the clicking noises inherent to the action of these units.

The silencing of the intermittent mechanism is at the present writing still one of the problems which confronts the cinematographic

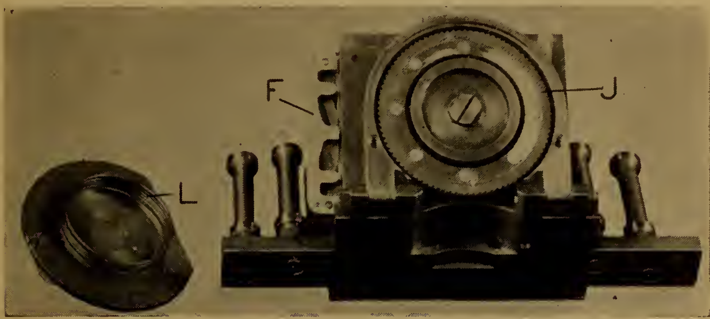

Fig. 7

Bell & Howell Super-speed mechanism, with cover plate removed. F—Check Pawls. J—Driving Gear. L—Anti-reverse spring. Showing the high-speed movement as used for sound work, equipped with Formica gear J. The relatively low speed required in this work permits the elimination of three pairs of film feeding fingers, which considerably reduces the noise of operation

mechanical engineer and upon its solution largely depends the freedom of the Cinematographer from the encumbrance of sound proof booths or similar appliances.

Power Transmission

The mechanism which transmits the motive power to the intermittent mechanism, has also undergone important changes of late in order to silence its action and has been made more adaptable to the taking of pictures synchronized with sound.

Although electric motors were quite extensively used in silent motion picture work in order to insure uniformity of speed and regularity when speeds other than the normal were required for special effects, the motive power was usually supplied by hand cranking the camera at a speed of two revolutions per second.

Trains of gears of great accuracy of design and construction are used for the transmission of the energy to the various parts of the apparatus at the desired speed and to the one or two sprockets which impart a uniform motion to the film before it enters and after it leaves the intermittent mechanism. The trains of gears are mounted on shafts which are held in position and centered by means of bearings. The energy transmitting mechanisms were designed with a view of ease of operation and with a reasonable disregard of the noises they produced. Gears were of hardened steel and bearings of the type known as ball-bearings, which insure great ease and smoothness of operation.

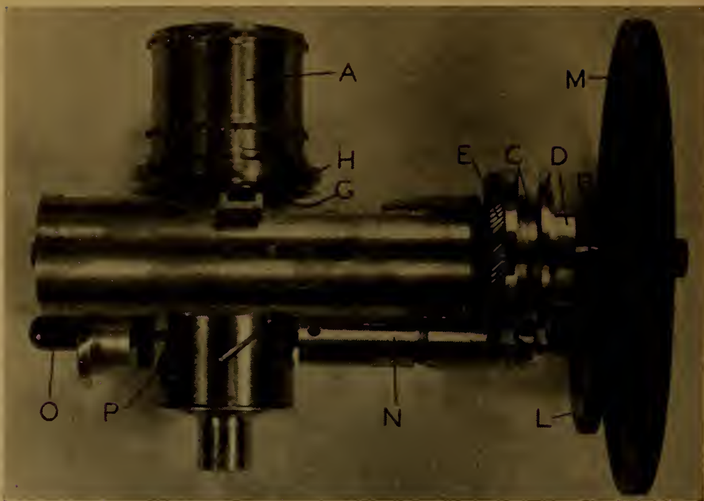

Fig. 8

Arrangement of Driving Units. Bell & Howell Camera (from above). A—32 Tooth Main Sprocket. B—Shutter Pinion. C—Register Leaves Control Cam Slot. D—Heart-shaped Shuttle Cam. E—Ultra speed mechanism driving gear. G—Shutter Dissolve Control Barrel. H—Magazine Take-up Belt Driving Groove. L—Shutter Driving Gear. M—Double Leaf Shutter. N—Intermediate Shutter Driving Barrel. O—Dissolve Operating Lever. P—Main Crank and Sprocket Barrel.

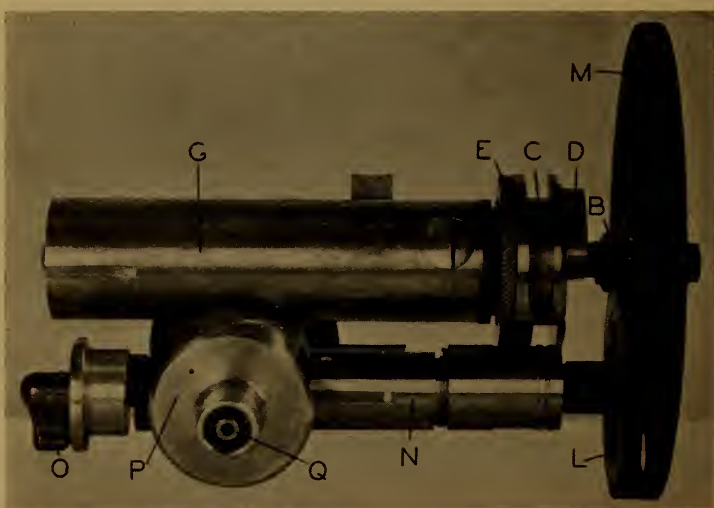

Fig. 9

Arrangement of Driving Units, Bell & Howell Camera. (Crank Side.) B—Shutter Pinion. C—Register Leaves Control Cam Slot. D—Heart-shaped Shuttle Cam. E—Super-speed mechanism Driving Gear. G—Shutter Dissolve Control Barrel. L—Shutter Driving Gear. M—Double Leaf Shutter. N—Intermediate Shutter Driving Barrel. O—Dissolve Operating Lever. P—Main Crank and Sprocket Barrel. Q—Crank Shaft.

The advent of sound pictures, however, due to the necessity of perfect synchronization of the speed of the camera with the sound recording apparatus, excluded entirely the human element in camera cranking and replaced the hand cranking with synchronous motors.

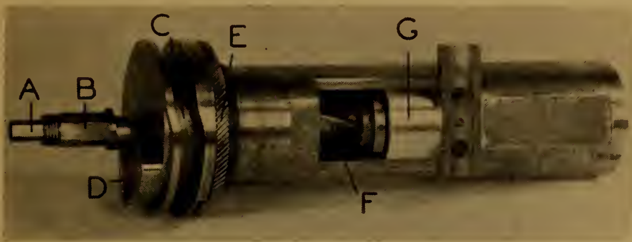

Fig. 10

Bell & Howell Camera Shutter Dissolving Barrel and Shuttle and Register Leaves Control Cams. A—Shutter Dissolve Control Shaft. B—Shutter Shaft. C—Register Leaves Control Cam Slot. D—Heart-shaped Shuttle Cam. E—Super-speed Mechanism Drive Gear. F—170 Spiral Shaft. G—Shutter Dissolve Control Barrel. The Bell & Howell Shuttle register leaves mechanism and super-speed movement are interchangeable, the first being controlled by cams C and D, and the second being actioned by gear E. The Shaft B rotates at a uniform speed, while the speed of shaft A, to which one of the two shutter leaves is attached, can be automatically altered to gradually reduce or increase the angular opening of the shutter.

This was a rather fortunate occurrence because it permitted the mechanical engineers to replace the ball bearings of the camera mechanism with solid ones thus eliminating the clicking noises which are unavoidable in the former. The solid bearings do not allow the same ease and lightness of running as the ball bearings, but this becomes of little or no importance because the motor drive eliminates the possibility of tiresome and uneven "cranking" of the camera.

Camera Shutter

From the earliest days of cinematography, the motion picture camera shutter has consisted of a rotating disk placed between the camera lens and the film aperture. The mission of the shutter is to interrupt the light transmitted by the photographic lens during the periods the film is in motion, while an open sector permits the exposure being made while the film is stationary.

In the early cameras the angular opening of the shutter was of 120°, or thereabouts, which permitted the exposure of each picture frame for 1/48 of a second when the camera was run at the normal speed of 16 pictures per second.

Through intelligent and precise design of the intermittent mechanism of the camera, it has been possible to increase the angular opening of the shutter up to 170° which increases considerably the useful amount of light transmitted by the lens.

The only camera known to the writer which departs from the disc system of shutter is the Akeley camera, designed for taking motion pictures of wild animal life. This camera is of circular shape and its shutter consists of a curtain running around its interior periphery. An opening in the curtain permits the image formed by the photographic lens to reach the camera aperture. The length of this opening is such that it corresponds to an angular opening of 230° of the regular disc shutter.

In the early days of Cinematography, the effects known as "fade-in" and "fade-out" or "dissolves", which involve a gradual diminishing or increasing of the intensity of light which reaches the film, were obtained by gradually reducing or increasing the aperture of the diaphragm of the photographic lens. This system, although quite efficient, did not present sufficient guarantee of evenness of operation and presented some difficulties in obtaining the correct exposure for two different scenes which it was desired to "lap-dissolve" into each other when their illumination varied considerably.

The double disc shutter with automatic dissolve solved the problem very nicely. Both leaves of the shutter rotate at the same speed in the photographing of normal scenes, but through a control acces-

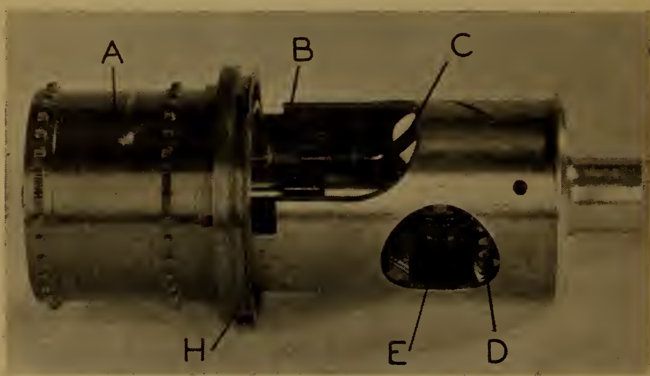

Fig. 11

Main Sprocket and Crank Barrel, Bell & Howell Camera. A—32 Tooth Main Sprocket. B—Train of Gears Operating Dissolve Mechanism. C—Oil Tube. D—Bevel Gear Driving Intermediate Shutter Barrel. E—Anti-reverse Dissolve Gear Mechanism. H—Magazine Take-up Belt Driving Groove. The 32 tooth film sprocket is solid with the crank shaft, so that for each revolution of the crank, 32 film perforations (8 picture frames) pass the sprocket. Train of gears B transmits motion to gears in the shutter dissolving barrel, which regulate the speed of the spiral shutter shaft and gradually open or close the shutter.

sible from the outside of the camera, one of the leaves can be made to rotate at an increased speed, and therefore while the camera is working at a constant speed the angular aperture of the shutter can be gradually reduced from its maximum aperture of 170° to zero or to any desired aperture between, or vice-versa—from zero to full opening or any desired aperture in a predetermined number of shutter revolutions.

The easily controllable variable aperture of the camera shutter is also useful for securing the correct exposure for each scene of a picture production without having recourse to variations in the opening of the lens diaphragm which involves alterations of the depth of focus of the lens and consequent unevenness in the photographic continuity of the photoplay.

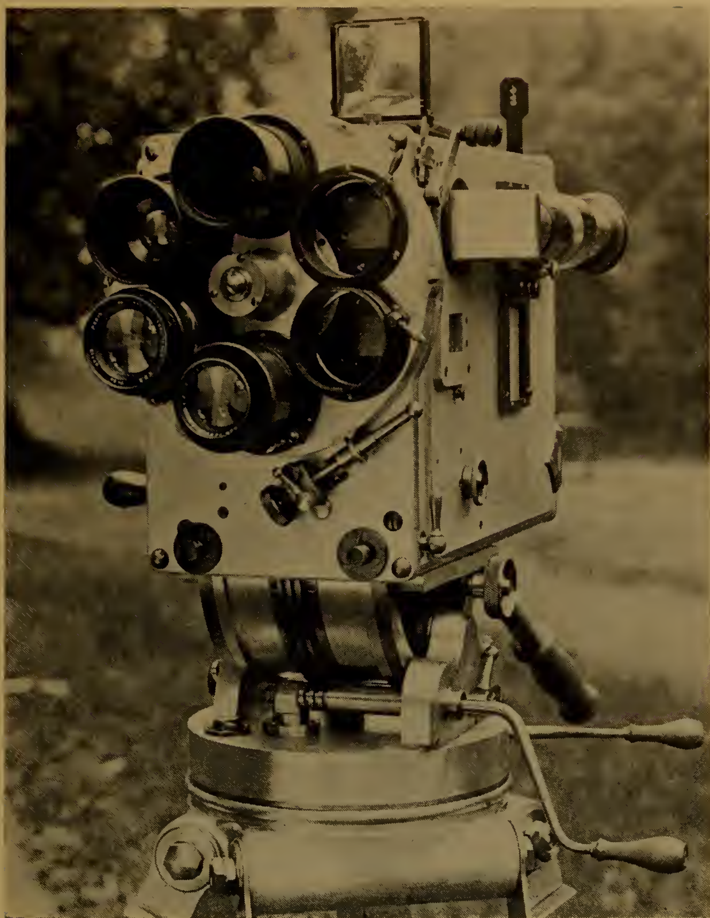

Fig. 12
Camereclair—(France.) Front View. Note six-lens turret, and ground-glass focussing screen in aperture directly above photographing aperture, with reflecting, magnifying focussing-tube.

Focusing

The first cameras which enjoyed a commercial success were of French manufacture: their outer casings were made of well selected and properly seasoned hard wood. The focusing was usually done through the film or by withdrawing the film from its channel and replacing the pressure plate with a piece of ground glass or by replacing the sensitive film with a piece of translucent material.

American ingenuity replaced the wooden casings by metallic ones and conceived the idea of building in the camera a focusing aperture independent from the film aperture. The Bell & Howell, the Mitchell and the Akeley cameras are, with variations of design, all equipped with this system of focusing which represents both a saving in time

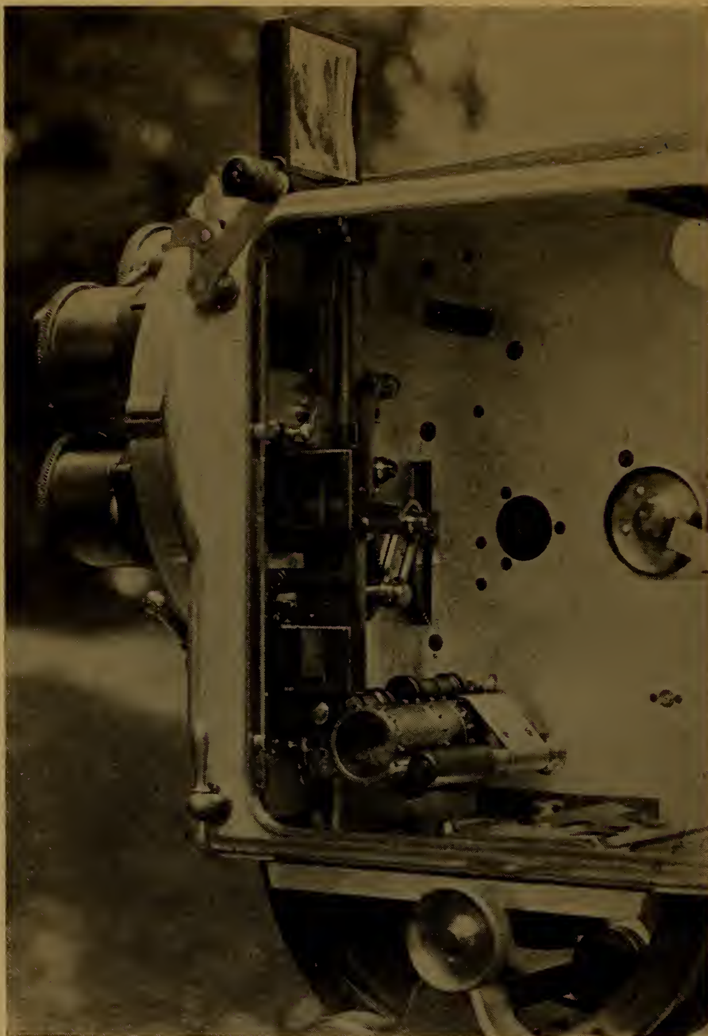

Fig. 13

Camereclair—France. Film Movement and Focussing Mechanism. Depressing lever at upper left corner of camera displaces film and permits accurate focussing on ground-glass screen without unthreading camera. With matched lenses focus can be followed during exposure, using ground-glass in upper aperture. It is also possible to focus directly on the film.

and a saving in film because it eliminates the necessity of opening the camera door each time that the need of focusing presents itself. More important than any economic consideration is the fact that the independent focusing aperture permits the moving of the camera from location to location without disturbing the registration of the film even in the most intricate lap-dissolves and multiple-exposure work.

European manufacturers have in the past few years been following the American system of focusing and the Debrie and Camèréclair

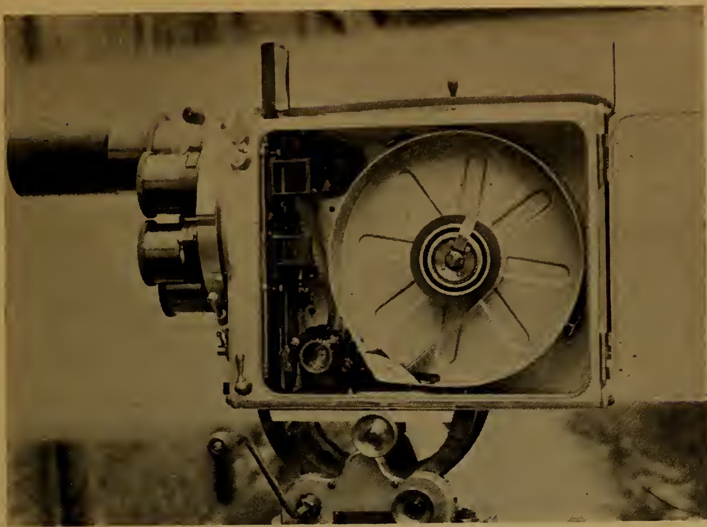

Fig. 14
Camereclair—France. Showing Magazines and Method of Threading.

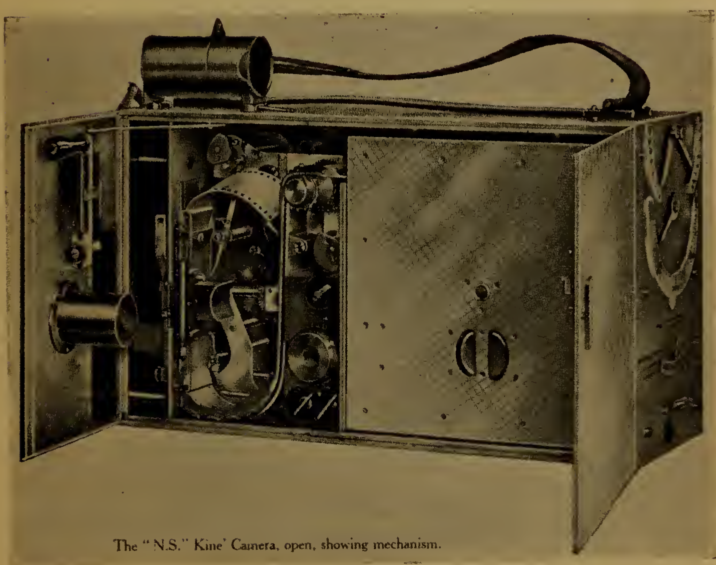

Fig. 15
Newman-Sinclair—England. Film Side, open, showing box-type magazines and method of threading.

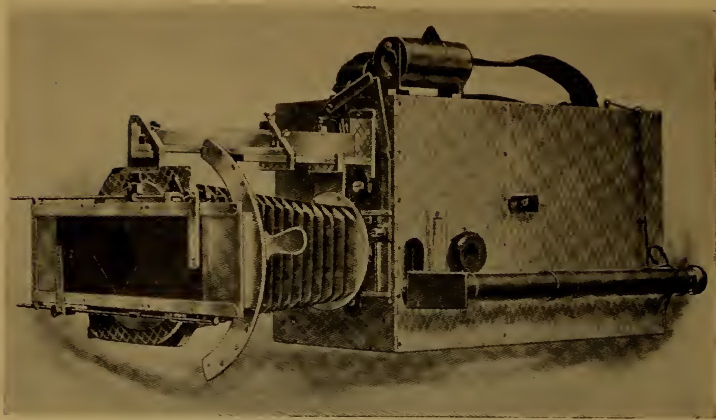

Fig. 16
Newman-Sinclair—England. Showing appearance closed, and method of attaching accessories.

Fig. 17
Williamson Camera—England. An excellent camera, typical of the earlier types of construction.

cameras made in France, and the Newman Sinclair made in England have been equipped with focusing attachments reaching the same effect as those of American manufacture.

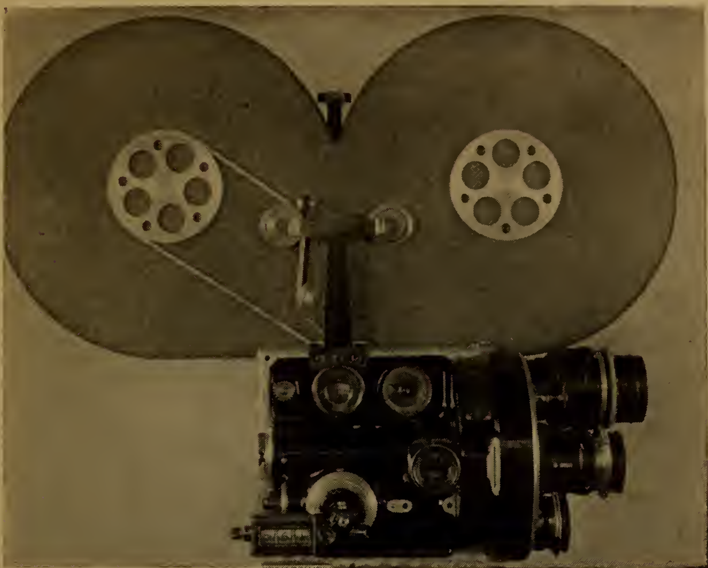

Fig. 18

Bell & Howell Standard 35mm. Camera, as Equipped for Sound Cinematography. Note 1000-ft. magazine and fabric belt with tension equalizer. Footage meter is attached directly to crankshaft to allow synchronous motor to be connected to the shutter dissolve barrel (stop motion) shaft.

Film Magazines

The most striking departure from European models, was perhaps the conception of American engineers of designing the film magazines.

In cameras of French design, these were mostly built in two units, one holding the raw film and the other serving as receptacle for the camera case. The latter method is the one most followed by European camera designers to this day.

The Bell & Howell Company introduced in America the double compartment magazine with special traps which would automatically open when closing the camera door and thus permit the film to leave the magazine and enter it after exposure without being submitted to unnecessary friction and all the evils proceeding from it.

One of the interesting problems which confronted the motion picture mechanical engineers was the necessity of compensating the gradual diminishing of speed of rotation of the film take-up spindle of the magazine, due to the increase of diameter of the film role, with the increase of film length being wound, while the film is fed to the camera mechanism at a constant speed.

This problem was solved in some European cameras, in which the feeding and the take-up magazines are set side by side, by design-

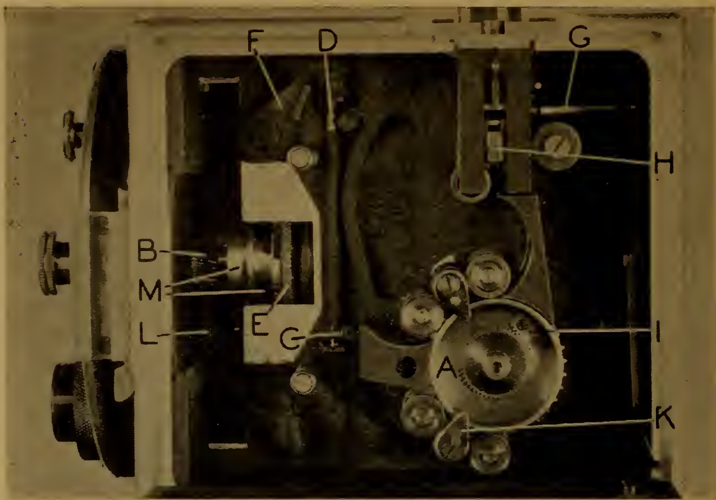

Fig. 19

Film compartment of Bell & Howell Camera, with Intermittent mechanism removed. A—32 Tooth Maid Sprocket. B—Shutter Pinion. C—Footage Indicator Gearing. D—Footage Indicator Gearing. E—Super-speed Mechanism Drive Gear. F—Intermittent Mechanism Locking Latch. G—Film Punch. H—Magazine Safety-valve Operating Mechanism. I—Main Crank Barrel bearing Adjustment Lock. K—Film Guide Rollers and Safety Lock Pin. L—Shutter Drive Gear. M—Shuttle and Register Leaves Control Cams. The camera is shown with its door to show accessibility of film compartment for loading. The intermittent mechanism has been removed to show the position of the shuttle driving cams and gear driving the super-speed movement.

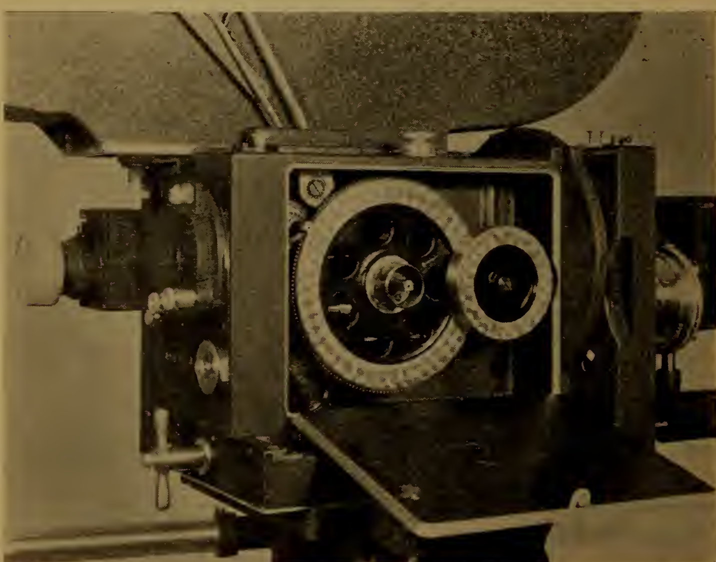

Fig. 20

Mitchell Sound Camera. Note use of Composition Gears to Eliminate Noise.

ing a mechanical differential movement. In American cameras and in some European ones, the take-up was secured through a metallic spring belt actioned by a pulley as an integral part of the camera mechanism. The belt would skip and slide over the magazine take-up pulley, whenever the latter would present sufficient resistance due to its rotating at a slower speed than the pulley driving the belt. Again, sound pictures, and the necessity of eliminating all mechanical

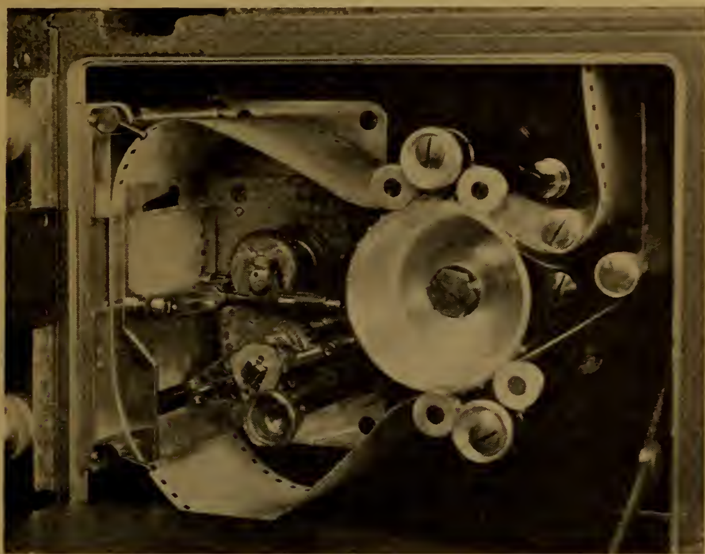

Fig. 21
Mitchell Camera, with High-Speed Movement as used in Sound Pictures. This is the Grandeur (70mm.) Model, which, except for width, is identical with the 35mm. model.

noises in operating the camera, brought about a radical departure from what was theretofore considered an essential principle of film take-up. Metallic spring belts were replaced by noiseless fabric belts, the tension of which is controlled by especially designed belt tension equalizers.

Generalities

No other adage is, perhaps, as true as the old "Necessity is the mother of Invention." Soon after Motion Pictures emerged from their swaddling clothes and made an attempt of entertaining audiences with more elaborate presentations than 25 or 30 feet of a train puffing into a station, or a few feet of a parade, and after Melies had given the world proof that the motion picture was the greatest Mystificator and Magician in the world, the cinema indulged in a long and successful career of comical productions which demanded effects which were designated with the appellations of "Fade-in" and "Fade-outs", "lap-dissolves", "double", or "multiple-exposures", "split screens", "stop-motion" and the like.

These few years which are recalled by many only as the "pie throwing" era of motion pictures and which are looked upon with

Fig. 22

Mitchell Automatic Belt Tension Equalizer. This is an outgrowth of sound pictures, which simultaneously demanded the use of 1000 ft. rolls of film, and precluded the use of the spring-belt of former days. In this case a leather belt is used, the spring-tension pulley arrangement automatically providing the correct tension as the diameter of the roll of exposed film in the magazine increases.

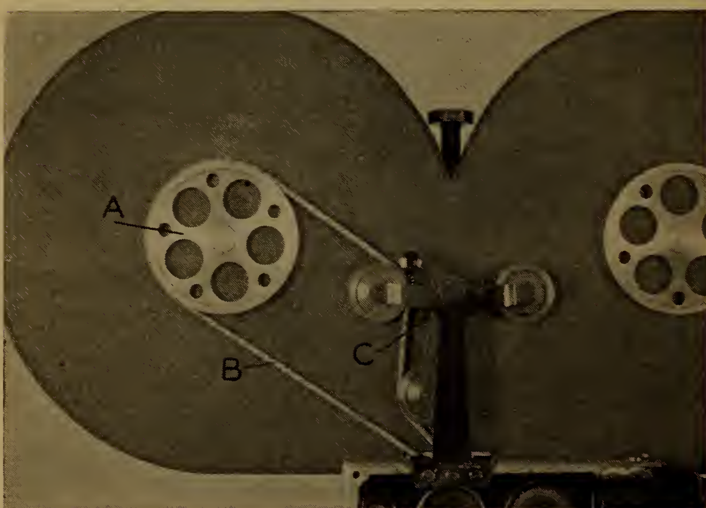

Fig. 23

Bell & Howell Belt Tension Equalizer. A—Magazine Pulley. B—Endless Fabric Belt. C—Belt Tension Equalizing Spring. This tension equalizer can be used for magazines of either 1000 ft. or 400 ft. capacity. The belt is threaded differently over the pulleys of the equalizer when using 400 ft. magazines, in order that the slack in the belt may be completely compensated for.

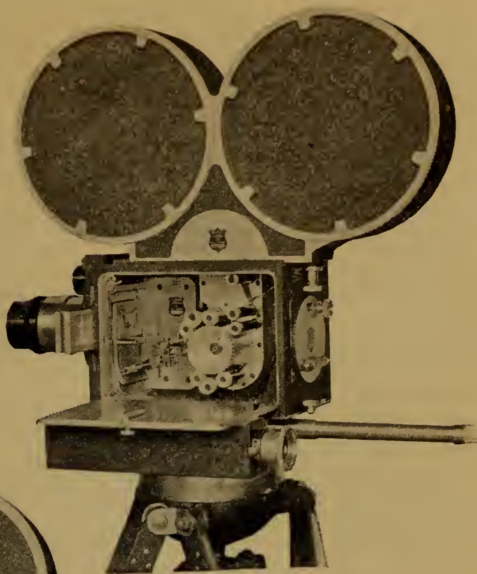

Fig. 24

Film Side of the New Fearless Camera. One of the outstanding features of this newcomer among professional cameras is the fact that it can be converted from a standard 35mm. camera to one using 65mm. film in less than ten minutes.

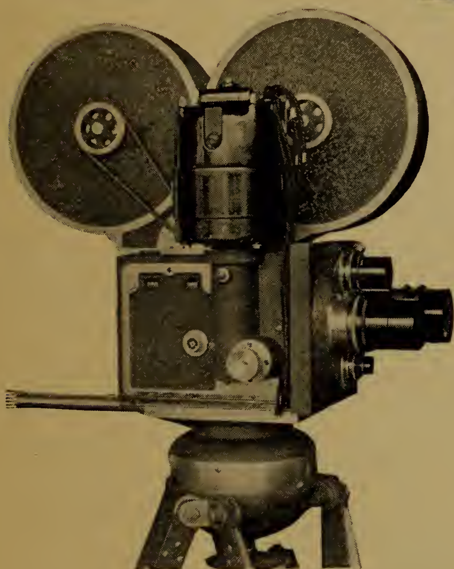

Fig. 25

Fearless Camera, showing method of attaching synchronous motor. The mechanism of this camera is enclosed in a sound-proof and oil-proof box, and runs in a bath of oil. The oil is further supplied to all bearings by a pressure system. This is said to make it one of the mor' noiseless cameras yet developed.

Fig. 26

The Akeley Camera. A unique camera built for use with rapidly moving subjects. It is the only cinema camera made to use a focal-plane shutter. Through its unique gyro-tripod head it is enabled to follow objects moving at any speed with perfect smoothness and accuracy; the object is followed as to focus and alignment by means of a matched lens and a magnifying focussing-tube.

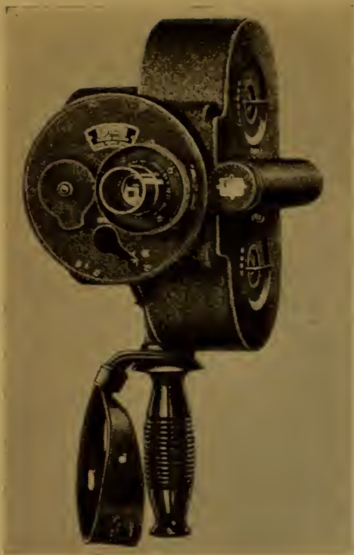

Fig. 27
The Bell & Howell Automatic Portable 35mm., Eyemo Camera. This camera is of the spring motor type, and holds 100 feet of 35mm. film. It is Daylight loading, and operates 50 feet at each complete winding of the spring. Three models are made: one, which can be operated at either eight or sixteen frames per second; one for use at either twelve, sixteen or twenty-four frames per second; and the third for moderate high-speed use, at 64 pictures per second.

scorn by the uninitiated have, however, been extremely prolific in the technical advances which made possible the more presumptious motion picture productions of today.

Tachometers were made part of the camera, eliminating the drudgery of the necessity of paying constant and minute attention to the mechanical details of operation of the instrument and permitting the Cinematographer to devote his energy almost entirely to the expressing of his artistic endeavors.

Vignetting devices of all sorts, independent from the camera, or made intrinsic parts of the instrument, were designed and became, in the hands of the Cinematographer, a potential means of expression.

Photographic objectives were improved in design and their apertures gradually increased to the truly remarkable speed lenses of today, and their mountings were devised with such extreme attention to design and construction that they permit the setting of the lenses within almost immeasurably close tolerances.

The necessity of portability spurred inventors to device automatic portable cameras with spring or electric motor drive such as the Bell & Howell *Eyemo*, the *DeVry*, the *Cinex* and the Sinclair *Auto-Kiné* which are as accurate in design, workmanship and operation as standard cameras.

The necessity of absolute and perfect registration in cameras, as well as in laboratory and projection apparatus presented such diversified and complex problems that they attracted the attention of some of the best recognized mechanical engineers, who, with the conservatism proper to engineering developments and the enthusiasm spurred by new ideals, created cameras so perfect in design that they took their rightful place among instruments of high precision.

The fear of the high cost of the product, which has sounded the death knell of many promising enterprises, was courageously dis-

Fig. 28

The Newman-Sinclair Automatic, Portable, 35mm. Auto-Kine Camera. (England.) This camera is of the spring motor type, being driven by two springs. The motor is regulated so that it varies less than two percent between the start and finish of the run. The speed may be varied at will. The camera holds 200 ft. standard 35mm. film, and will expose from 150 to 180 feet with one wind of the clockwork. An interesting feature of the design is the fact that both the footage indicator and the level are visible through the finder while photographing.

carded by the motion picture industry as being contrary to common sense and little by little the knowledge acquired through years of experimentation and progress led to the standardization of dimensions, the absence of which imperils any commercial enterprise.

Motion picture mechanical engineering became an art in itself and research laboratories, mechanical manufacturing centers, and technical and engineering societies came into existence all contributing to the advancement of the motion picture art and to its establishment as a potential factor in the educational and entertainment fields of our social system.

Editor's Note: Since Mr. Dubray's article was prepared the Fearless Camera Company has brought out a new camera, especially designed for making pictures on 65 millimeter film, and also designed so it may be used as a standard 35 millimeter camera. A complete description of this camera will be found in the special article on Wide Film.

South Seas

COMPOSITION IN MOTION PICTURES

Daniel Bryan Clark, A. S. C.

THE word *composition* is one of the most frequently used, and often one of the least understood, of the many used in discussions of visual art. For this reason many people feel that it is something mysterious and incomprehensible, which only the elect may understand. This conception of composition is as accurate as the conception of all mathematics as being involved and incomprehensible; differential calculus may be intricate, but it is no more mathematics than the basic principles of addition and substraction with which our school-children begin. And the basis of all composition is merely arranging the parts of a picture so that the whole is pleasing to look at. From this simple beginning, composition can develop into an intricate art and science, but it always remains, essentially, the art of arranging a pleasing picture.

The art of composing motion pictures is the keystone of successfully photographed productions. This is true because good or bad composition dictates the success or failure of the story, and, after all is said and done, the photography must show the thoughts of the director, the performance of the actor, and the mood of the writer. These three form the story. Therefore, unless the work of author, director, and actor are composed properly in the final picture or series of pictures, the result of their combined efforts is more or less a failure. So, composition is, or should be, one of the chief aims of the cinematographer in charge of the production. His other essential aim should be to produce a clear, technically perfect negative by the use of his understanding of lights and shadows, and by his skill in handling the camera and its accessories.

The means of composition are many and varied. The space allotted me here does not permit going into detail about these tools, but in order that the reader may become more familiar with the methods that produce the picture which the theatre-goer actually sees on the screen, I will survey a few of the elementary principles of composition, and trace their practical application in making a picture.

The natural laws of composition were discovered long before the cinematographer came to add a composite record of action to the remarkable story of civilized humanity. Even the Old Masters of brush and canvas had to grope back into time for the key, and even they could not find from whence it came. The story of Art does not reach far enough into antiquity to specifically state who discovered the natural law of optics which is the essential principle of composition, yet all of the art of the cultivated ancients shows that its application was known.

Modern tests have proven that on the motion picture screen, as well as on the printed page, or any other field, the vision strikes the lower left-hand corner and travels naturally upward and to the right until some object in its path arrests or diverts the eye to some other path. *The proper placing of these guiding objects constitutes the basic secret of composition.*

It is possible to arrange a scene so that the vision is led or guided to any desired spot, and held there, suspended and waiting, even though action is taking place at another place in the same field of vision. It is the skill exhibited in doing this that differentiates the artist from the "crank turner." By composing the set and the actors on it, the skillful cinematographer can make identical action difficult or easy to follow. The cinematographer's ability to compose is often the means of clarifying otherwise difficult parts of a story.

To do these things, the cinematographer has almost unlimited resources at his command. On interior sets he has, in addition to the design of the set itself, the entire resources of the property department, which can supply him with furniture, plants, hangings, distinctive rugs, and every conceivable manner of inanimate objects. Furthermore, he has his living actors, whose places and movements can have a great part in making his composition. And, above all, he has the infinite possibilities afforded by the use of his lighting equipment, which he can control down to a very fine point. When you sum all of these factors up, you can begin to see how thoroughly the cinematographer can control the product of his workmanship.

In exterior scenes the cinematographer has many natural objects to work with; he may compose with trees, streams, fences, rocks, or even small bushes properly placed to guide the vision of his audience. Furthermore, in modern production cinematography, he has many artificial aids in composing his picture. Aside from the use of artificial trees, rocks, etc., which he can have placed where he wants them, he has at his command the photographic aid of filters, gauzes, diffusers, reflectors, and, more and more, of supplementary artificial lighting equipment as well.

The proper use of these aids and objects in composing a scene is almost solely the duty of the cinematographer. The director orders the words and actions of the actor, but upon the cinematographer rests the responsibility for capturing the vital points of the story in such a manner that it is easy for the spectator to follow the unfolding of the dramatic action. It would be next to impossible to read even the most interesting book if the printing were composed backward. One would be mentally worn out trying to read a single page, and would no doubt put the book aside without further efforts to absorb its contents if it were not for the fact that the printer has always followed the natural laws of optics. In exactly the same way the cinematographer must use that law to gain and hold the attention of the motion picture patron.

A pleasing story is seldom a pleasing screen display unless it is properly composed according to cinematographic standards. On the other hand, an unpleasing subject in story matter can be converted into pleasing entertainment by a master composer. As a famous screen critic recently wrote, "It is impossible to write motion pictures with a pen. The necessary creative process can be accomplished only with a camera."

These statements may seem biased and far-fetched to some readers, so let us by way of illustration briefly trace the course of a story from the pen of the author to the screen of the theatre, and point out the influence cinematographic composition can have upon its success or failure.

In the beginning, the author has an idea which his experience tells him is the germ of a good story. He proceeds to transfer it to paper, and to develop it as his experience tells him a successful novel or play should be developed.

The producer reads the story, or sees the play, and his judgment

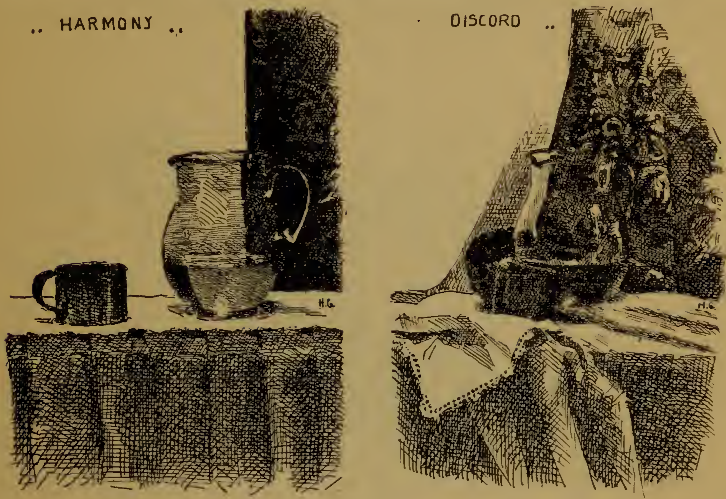

Fig. 1

tells him that it will make a good picture from a commercial as well as an audience standpoint. Accordingly, he buys the story.

In his turn, then, the producer passes the story on, together with his ideas upon its treatment, to the scenarist, who prepares the script of the photoplay, injecting into it his own thoughts and ability as a writer of screen plays, along with the original ideas of the writer and producer. This accumulation of thought he passes to the director.

The director then adds the benefits of his experience to the preparation of the script, which will ultimately be a picture—or, in fact, a series of thousands of successive pictures which, as far as the audience is concerned, will merge into one living picture called a photoplay. Thereafter the director, with the aid of his assistants, proceeds to choose a cast and to have sets designed which, in his estimation, are the most perfect representations of the characters and settings as conceived by the author, producer, and scenarist.

During this period, the chief actors are studying their parts, and preparing to add their conceptions of the parts to this rapidly mounting accumulation of thought and work. But, up to this time the photoplay is only a mental conception. It consists of the author's description of his mental picture of the story; the producer's thoughts of its entertainment value; the scenarist's described visualization of the ultimate film; the director's mental concept of the whole and its component scenes; and the actors' mental pictures of their portrayals of the characters.

Here is where the cinematographer begins to fit into the plan of things. It is his task to make this combined total of mental pictures into an actual, lasting record; to take the combined efforts of all the others who have put their minds and efforts into the pictures, and make a condensed, objective version of their thoughts. This must be accomplished by arranging a series of compositions and then bringing them through a small piece of glass called a lens, onto a light-sensitive film which will preserve them as a lasting, physical record

Fig. 2

Knowledge—by Henry Goode. Attention is focussed on the face and figure of the sitter.

of all this expenditure of thought and money. Unless the cinematographer can make this record a perfect crystallization of all these mental concepts, all that has gone before is wasted. Here is where a thorough knowledge of composition proves itself invaluable, for by arranging his subjects, lighting, and color scheme properly according to the laws of composition the cinematographer can, without detraction from the story, give a rendition of half-tones, high-lights, and shadows which will be in keeping with the mental pictures already created, and which will enhance the efforts of those whose ability and mental pictures he is, in the highest sense, trying to compose.

Occasionally a cinematographer will be called suddenly onto a picture, and forced to start it knowing little or nothing of the moods and mental impressions he is endeavoring to portray. This system is invariably expensive, and results either in unsatisfactory photography or in added time necessary to secure good photography. Such a condition is distinctly felt by the audience, though not in the same direct way that an unsatisfactory acting performance is. Instead it talks the form of an intangible feeling that something is wrong with the picture. Nowadays, however, this situation rarely occurs with the better producing organizations, since they are aware of the influence which good cinematographic composition lends to a picture, and insure themselves by retaining the best possible cinematographers, and by encouraging them to become familiar with story, director, and general conditions as far beforehand as possible. The cinematographer must take these combined artistic, mental, and psychological factors and express them by a series of compositions which will match the various moods involved, and be pleasing to look at. To do this, he must be a first-class artist. His brush is the camera, his paints all the many factors by which he attains his compositions—people, sets, trees, houses, streams, "props," lights, filters, gauzes, diffusers, etc.

Fig. 3
Knowledge—by Henry Goode. Attention is focussed on the book.

With these and his understanding of their use, he must paint a picture for the world to look at, enjoy, and criticize. His canvas is a negative film, upon which he must register his picture by proper exposure so that the positives can be printed for release throughout the world. His greatest handicap is the disparity between the tiny canvas upon which he paints and the vast ones upon which the world will view his creation. The individual "frames" upon which he composes his picture are but ⅞″ x 1″, while the screens upon which his compositions are projected are as much as sixteen thousand times larger, so that as many as 6,000 people can simultaneously view his work. With this terrific enlargement comes a proportionate magnification of his efforts, be they good or bad. Unlike the artists who work with brush and canvas, and whose pictures need show but a single phase of motion, the cinematographer's composition deals with motion itself, and must flow and change, and still fit together with the smoothness of fine music. Therefore the necessity for thought in composing is immediately apparent.

One often finds an artist who will not admit that he is guided by any law of scientific composition—who claims that he is a law unto himself. Frequently such an artist will make a success, but if one studies his work, it will be found that either he is subconsciously using the fixed laws of composition, or else deliberately copying the methods of those who do use the rules. Such a man will be a success for a time on account of his inherent talent, but sooner or later he must fall backward in the march of progress because of his lack of true knowledge and early training.

All nature was made to select compositions from, and there can be no arbitrary "Thou shalts" or "Thou shalt nots" in the treatment

Fig. 4
Time and Light—by Henry Goode. Attention directed to the figure.

of them as long as the artist conforms to the natural laws of composition and vision, and systematizes his work so that no outside influence can interfere with his freedom of expression. The conclusion I have reached after a long study of composition and its possibilities as related to cinematography is best expressed by the phrase that "Art is not *What*, but *How*." It matters little *what* the subject to be photographed may be, as long as that subject is arranged properly. Any student of photographic art has, I am sure, either attended some of the numerous salons held throughout the world, or studied the reproductions of salon prints in the many excellent photographic magazines published. In them he will undoubtedly have noticed how merely through mastery of the technique of artistic photography and, especially, of pictorial arrangement, or composition, even the most commonplace, prosaic, or even repulsive subjects have been made into beautiful pictures. Not the subject, but the manner of presentation, made them fit to be exhibited in a concourse of photographic beauty.

There have been many "systems" of treating composition, but perhaps the best and most popular of them is that of *Dynamic Symmetry*. An excellent treatise upon this subject was written by Jay Hambidge, and is well worth reading by everyone interested in the more technical phases of pictorial art. The principles of dynamic symmetry can be used as well by cinematographers as by the painters and architects for whom the system was originally expounded. In cinematography it can be employed in arranging the compositions so as to conform to the dynamic lines and areas, which guides may very

Fig. 5
Time and Light—by Henry Goode. Attention directed to the book.

profitably be drawn on the ground glass focussing-screens of the cameras.

Under any system, the cinematographer always looks for some dominant and characteristic angle, either of the grouping, or, if the shot is merely of a head, for some basic form suggested by the subject. He makes this the foundation of his plan of composition, and from it creates the fabric of the whole in like terms. The finished picture is, therefore, like a flower which has grown from a seed; it hangs together, and every feature is an outgrowth of the basic theme —the story. Dynamic symmetry is simply a system of charting composition within a given field by dynamic lines, and symmetrically placing the subjects accordingly. To the cinematographer, this field is the aperture of the camera, or, in the final analysis, the screen of the theatre. The artist of brush or pen actually draws a chart to work with; the cinematographer uses the same chart, but it is a mental chart, necessarily more flexible, and applicable to any and all subjects. With the coming of wide film a thorough understanding of

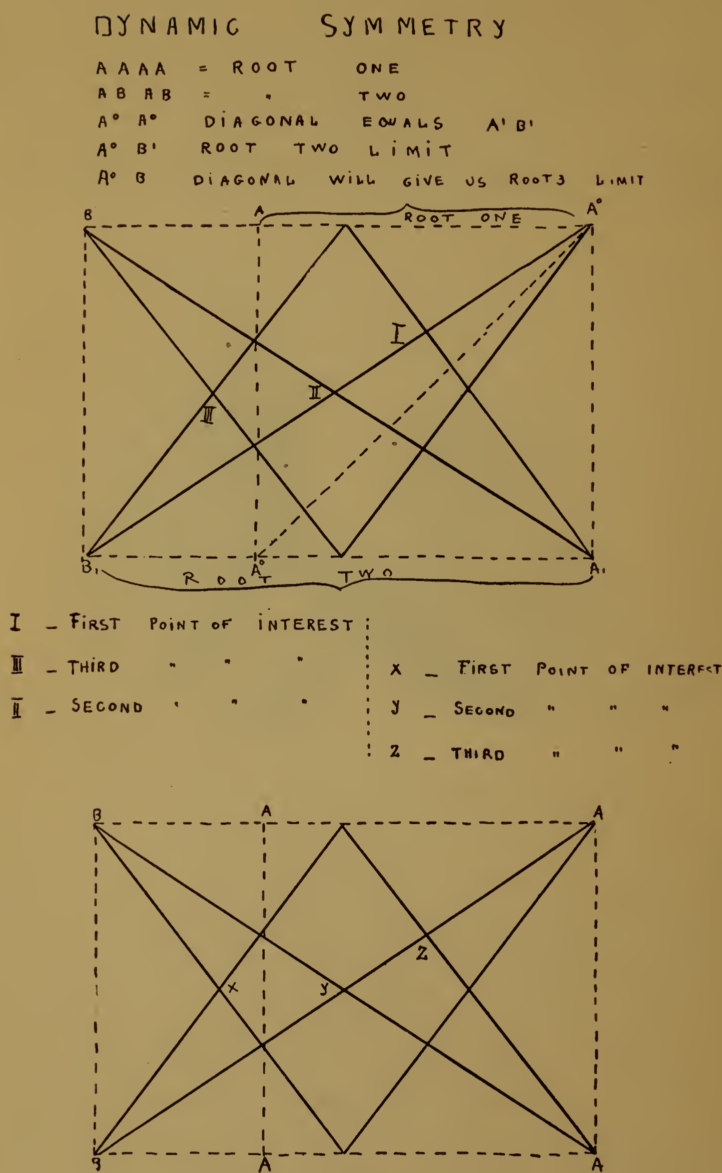

Fig. 6
Chart of the areas of Dynamic Symmetry.

dynamic symmetry becomes more than ever valuable, since we now have a more dynamically proportioned field to compose upon. These new dimensions in no wise call for a change in the system, but only give the cinematographer greater problems and greater possibilities for artistic achievements. The accompanying chart shows the relative dimensions of the 35 mm. field (and the effect of the sound-track upon it) and the new *Grandeur* or 70 mm. field. One can readily see the greater possibilities for dynamic construction offered by the latter.

Dynamic symmetry reminds me of the explanations of Greek architecture: perfectly simple and natural if considered from the syn-

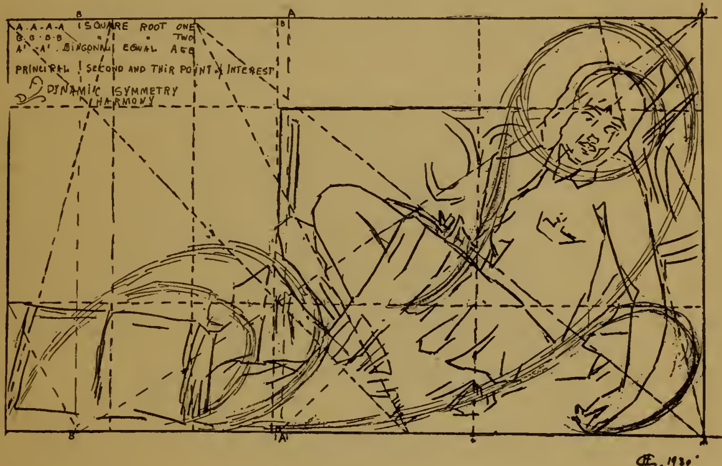

Fig. 7

Dynamic Symmetry Chart as applied to Figures 2 and 3.

thetic, or Artist's standpoint, but involved and very difficult if considered from the analytic point of view. Yet in practice all pictures are expressed by dynamic lines. For instance, we know that a composition stressing the vertical lines suggests dignity, while horizontal lines suggest repose, and diagonal lines generally suggest action.

The accompanying illustrations excellently demonstrate the fact that art is not in the subject but in the treatment. These etchings were presented to the American Society of Cinematographers by Henry Goode, the eminent Hollywood artist and musician whose work they are. In them he has arranged his compositions according to the system of dynamic symmetry. The first two, "Harmony" and "Discord," speak for themselves. In the second two, Mr. Goode has taken a subject which he is pleased to call "Knowledge": although it is exactly the same in both cases, he has demonstrated how the eye can be made to concentrate upon the desired spot by treatment alone, although in both instances the subject and pose are identical, and the same law of composition was followed. Yet in one case the attention is centered upon the face of the sitter, and in the other, upon the book. In the next two illustrations he shows an inspiration of *Time and Light*. In these the eye is guided almost entirely by a composition based upon the laws of dynamic symmetry, yet in the first case, the object of most interest is the figure, and in the second, the book. The factor which is responsible for this difference is so minute a detail as to be almost unnoticeable, yet it is none the less the dominate factor in the composition. *It is merely the position of the index finger of the subject's left hand,* yet in one picture its curve allows the eye to pass by to the figure, unhindered, while in the other the dynamic line formed by the extended finger shunts the attention immediately to the book. Obviously, such details as this cannot be overlooked in cinematographic camera work, where they are just as powerful as in an etching or painting. The accompanying chart explains how these principles of dynamic symmetry were used in the illustrations, and will suggest how they can be adapted to screen camera work.

After all, Art is Composition, and Composition, Art. The perfection of the whole consists in perfection in every detail. This perfection of Art must come through the employment of a comprehensive system of laws, commensurate to every purpose within its scope, but concealed from the eye of the spectator; and should result in the production of effects that seem to flow forth spontaneously, as though controlled by such laws. Such results should be equally excellent whether regarded individually or collectively—with regard to the components or to the proposed whole. That is artistry—obedience to the laws of art without the loss of spontaneity; the practical realization of the saying that "Art is not *What*, but *How*."

PAINTING WITH LIGHT

Victor Milner, A. S. C.

THAT cinematography is now being recognized as an art-form along with the established ones is due solely to the fact that studio cinematographers have become conscious of the fact that cinematography does not consist merely of the routine operation of a machine called a camera, but of creative, pictorial artistry. None of the "old masters" were more truly artists than the scores of Directors of Cinematography who supervise the photography of the photoplays being produced in the studios of Hollywood. In both cases, the artist's aim is the creation of beauty or character. The problem of both is the production of an illusion of roundness and depth on a flat surface. While the physical means employed are different in the two forms, in the final analysis we can see that the essential tool is the same; for, both on the canvas of the painter and the screen of the cinematographer, these effects, together with those of mood and character, are secured by the careful manipulation of light and shade.

One need only view a few great paintings, or see a few great photoplays to realize that, although all artists paint with the same tool—light—the manner in which they utilize it is in no two instances identical. One could never confuse the technique of Rembrandt with that of Gainsborough or Corot; neither can one confuse the cinematographic technique of any two equally outstanding cinematographers. While the basic principles from which all work are the same, the practical application of them—the actual manipulation of light and shade—is a highly individual, personal matter. Therefore, in such a necessarily brief and impersonal consideration of the matter as this must be, we can only treat lightly upon these basic principles.

The problem underlying the entire structure of cinematic lighting is that imposed by the mechanical factors involved. In the first place, a sufficient amount of light must be cast upon the area before the camera so that an adequately exposed negative will be obtained with an exposure of 1/51 second (i. e., a shutter opening of 170 degrees with the camera operating at the standard sound-track speed of 90 feet per min.) upon a sensitive material working at a speed of approximately 700 H. & D. To this end, it is the usual practice to lay a general foundation of even, diffused light all over the set so that there will be the desired degree of luminosity in the deepest shadows. This general lighting is best secured from above, by means of diffused Mazda strips and mercury-vapor banks. This general light governs the depth of the shadows, and from it one builds up to the required half-tones and highlights. Since the coming of sound pictures this general illumination is doubly important, for it smooths the way for the many cameras used in photographing dialogue sequences. While in the past the average number of cameras used on an ordinary set was no more than two or three, covering identical areas, the average now ranges between four to fifteen cameras, photographing the action taking place from different angles and with lenses of varying focal lengths, each working under more or less differing light conditions. For this reason, strict adherence to the policy of first insuring an adequate foundation of general lighting is the only salvation of the chief cinematographer of a talking picture. Furthermore, having this

Fig. 1
How lighting creates an illusion of depth and roundness. Notice the high-lighting of arches and furniture, and the use of cast shadows in this scene from "The Return of Dr. Fu Manchu."

general lighting come from the overhead units has the very practical advantage of conserving floor space, already overcrowded with camera-booths and the like.

Having satisfactorily arranged this general lighting, the next step is to determine what is to be the principal source of light for the set. That is, are there large windows, through which the light may seem to come, on one side of the set or the other; or are there lamps, chandeliers, etc., for the same purpose, if the scene is a night interior? Aside from the matter of determining what kind of light (i. e., simulated daylight or artificial light) shall be used, this apparently trivial detail has an important bearing upon the dramatic action of the film, for if the visible light-source were wrongly-positioned, the lighting might easily become such that it would affect the pictorial composition of the scenes to so great an extent that it would seriously detract from the desired effect. For this reason, as well as for several other equally practical considerations, such as ensuring the proper color-schemes, it is always advisable for the chief cinematographer to be thoroughly familiar with the script as long before starting work as possible, and then to work in close cooperation with the Art-Director who is to design the sets of the film. In this way, many costly errors and delays can be avoided. However, having determined the visible source of his light, the cinematographer should thereafter build up his lighting scheme with the view of retaining that illusion.

At this stage the problem of arranging the lighting to create an illusion of depth and roundness appears. At best, this can be only an illusion, but in the hands of a capable cinematographer it can become a very successful illusion indeed. The first of these effects—depth—is secured by the simple expedient of contrasting the lighting of the more important planes of the picture. That is, for instance, by silhouetting the foreground against a more brightly-lit middle-

Fig. 2
An excellent example of natural "source lighting," from "The Singer of Seville." The window at the left offers a natural source from which the light appears to come.

ground, which, in turn, may be contrasted against a darker background, or vice versa. These contrasts need not be too pronounced: in fact, in most cases, excessive contrast is definitely undesirable. There should be ample detail in the silhouetted planes, while the more highly lighted ones need not be so brilliantly lit as to appear 'washed out.' In other words, the contrasts can be carried out just as well in half-tones as in the absolute extremes of light and shade. Another aid to creating the illusion of depth is highlighting the walls of the set, leaving the various pieces of furniture just in front of them to become slightly silhouetted. In this connection early cooperation with the Art-Director is again essential, for if the set is designed properly, with enough irregular surfaces in its walls—sections recessed here, or jutting out there, and with bay windows, portieres, etc.,—the cinematographer's work is immeasurably easier and faster. Another aid is that offered by cast shadows, which also serves to separate the planes one from another, and to separate furniture, and the like, from the walls and floor.

The effect of roundness is secured through the judicious use of highlights. That is, placing little spots of light at the right points on curved surfaces, to accentuate the curve. Highlights are inevitable wherever there are curving surfaces—they are one of the chief natural aids to the visual perception of roundness—and the trick of placing them where they will do the most good is an important part of the cinematographer's art. For instance, if a set contains an archway,

Fig. 3
An example of "Impersonal" lighting from "The Love Parade." Notice that the lackeys are as favorably lighted as the stars.

with columns, etc., the columns can be made to seem round and natural if they are highlighted from one side or the other. The proper highlighting of arches not only gives roundness, but also depth. Similarly the highlights on furniture can serve identical purposes. This is especially true of the lower parts of the furniture—table and chair legs, etc.—which can be separated from the surrounding floor and wall surfaces and made to appear solid and three-dimensional by means of intelligently-placed highlights.

Of course the players should receive the most attention, as they furnish the principal interest in any picture. The sets should always be subordinated to them. As far as the players are concerned there are two kinds of pictures: one is the "star" picture, in which everything is subordinated to the "star"; the other is the "all-star" picture, in which no member of the cast is deemed superior to the story. These two types of picture require different types of lighting: the first, personal lighting, in which everything is subordinated to making the star look beautiful; the second, impersonal lighting, where photographic art and story requirements are paramount.

Personal lighting is, fortunately, rapidly disappearing, for the so-called "star system" has been recognized as one of the great handicaps of the industry, as it retards the production of the best pictures, since story, treatment, direction, cast, and photography have all to be tailored to fit the personality of the star. So many inferior "star" pictures have been foisted upon the public that the injuries this system has worked upon the more obvious production details are well known; while the ill effects it has had upon cinematography may not

FIG 4
A scene from the light comedy "The Love Parade." Contrast treatment of this with that of similar dramatic scene in Fig. 5.

be so glaringly apparent, the harm has been no less marked. In the first place, regardless of what the story may call for, the star must at all times be so photographed as to be the outstanding feature of the scene. This is a hardship alike upon the director and the cinematographer, for there are times when even an extra may be of more dramatic or artistic importance than this famous profile, or that famous pair of nether extremities. In addition, a star must always be so photographed as to be perpetually at his or her best. No matter whether the action be taking place in a dungeon or a ball-room, the star must be kept beautiful, with never a suspicion of a shadow upon the famous face or form, and, regardless of the setting, a beautifying halo of back-lighting following her around the set. That this is generally illogical and inartistic carries little weight with people whose inflated egos are backed up with contractural requirements for perpetual photographic partiality.

The second class—impersonal lighting—is, fortunately, becoming more and more the rule, for it allows the cinematographer to make the most of each scene. If it will aid the action to permit a shadow to cross the face of a principal player, or even to make her downright ugly, for the nonce, it may be done, and while it is the aim and the desire of every cinematographer to make all his people look attractive at all times, he is not hampered by having to make them so at the wrong time, or to make them photographically prominent when they should, for the time, be subordinated to someone else. In impersonal lighting the ideal is artistic rather than individual effectiveness. Under such conditions, if a featured player has a scene with an unknown extra, the only discrimination, photographically, between the two is based on the dramatic and artistic requirements of the scene: all other things being equal, both will receive the same

Fig. 5
In this scene from "The Return of Dr. Fu Manchu" observe how the low key lighting contributes a sombre effect foretelling heavy drama.

photographic treatment. Such a condition allows the skill of the cinematographer to evidence itself, for here lighting for the mood of the story becomes possible. Truer modelling of faces and forms, a finer quality of photography in general follows, and the elimination of the glary and artificial lighting which is so often a corollary of the star system adds realism to the story.

This condition makes possible the highest development of artistic cinematography—the creation of dramatic mood in the lighting. *In a well-photographed picture the lighting should match the dramatic tone of the story.* If the picture is a heavy drama, such as *"The Way of All Flesh," "Lummox,"* or *"The Case of Sgt. Grischa,"* the lighting should be predominantly sombre. If the picture is a melodrama, like *"Dr. Fu Manchu,"* or *"Alibi,"* the lighting should remain in a low key, but be full of strong contrasts. If the picture is, on the other hand, a light comedy, like *"The Love Parade,"* the lighting should be in a high key throughout, for two reasons: first, to match the action, and, secondly, so that no portion of the comedy action will go unperceived. In the hands of a skilled cinematographer the lighting of a picture can not only heighten the dramatic atmosphere, but, like an overture, subtly prepare the minds of the audience to be in a receptive mood for that type of action.

It must not be imagined that these effects are possible only on studio-made interior scenes. Quite the reverse! Since they are primarily the result of controlling light, it follows that they are possible wherever light can be even partially controlled. Therefore they can be attained equally well in normal exterior scenes if the cinematographer knows how to control and modify the natural light he works with. Of course the most obvious means of controlling light in an

Fig. 6
A typical "Personal" lighting example from "The Vagabond King." Notice how both lighting and composition favor the star at the expense of the supporting players.

exterior scene is through the exposure, and through the use of gauze mattes placed before the lens, to give varying degrees of diffusion to the picture as a whole, or to any individual part thereof. Such gauzing of parts of the picture can be a very useful aid in emphasizing or subordinating many details, but it has its definite limitations, so, while gauzing will always be an inseparable part of cinematography, it is only one of the devices by which studio cinematographers can control the light on their exterior scenes. The next is an outgrowth of gauzing; in fact it is gauzing on an enlarged scale. Instead of using only an inch or so of gauze in the matte-box of the camera, several yards can be used in the form of a large screen erected behind the actors, through which only a darkened and diffused image of the

Fig. 7
A striking example of night lighting from "The Light of Western Stars." By day this would be an ordinary shot.

Fig. 8
The remarkable atmospheric value of this scene from "Anna Christie" is due to careful arrangement of the lighting.

background is visible. This serves to contrast the lighting of the two planes, for the actors can be quite strongly lighted, yet move freely against a uniformly low-key background. If it is then desired to contrast this plane against a low-key foreground, as might be done in the studio, this, too, is possible, and can be done in several ways, as the nature of the location may dictate. Perhaps the simplest way is to have a shadow in the foreground—either taking advantage of the natural shadow of a tree or building, or placing such an object there to cast the desired shadow. Also, the shadow may —and very often has—come out of a paint-pot! In other words,

Fig. 9
The trench lighting from "Journey's End" illustrates how perfectly a dramatic mood can be preserved in a night exterior

the area which it is desired to have dark can be effectively darkened by the use of an ordinary compressed-air painters' spray and a little black paint. If, on the other hand, it is desired, as in, say, a love-scene, to have the actors move in a more soft, diffused light, with the background brightly contrasted, it is a simple matter to have a large muslin or cheesecloth diffusing-screen made and supported between the actors and the sunlight. This will diffuse the light upon them to any desired degree, while the background (and, if desired, the foreground, too) undiffused, will stand out strongly in contrast.

This, at last, begins to approach a true control, of the light; the next step is the use of reflectors. These have become such an important and inseparable adjunct to the making of exterior scenes that it is difficult to conceive of a motion picture troupe ever venturing away from the studio stages without a full supply of them. It isn't hard to realize the worth of reflectors in casting light into dark corners, and onto the shadowed sides of the actors' faces, but their value only begins there, for reflectors, like the lamps within the studio stage, can give several different kinds of light: the strong, hard light of the highly-polished reflector, or the soft, diffuse light of the ordinary one, while either of these may come from gold- or silver-reflecting surfaces, giving different photo-chemical effects. Naturally, with such a resource as this at his command, the cinematographer begins to find

Fig. 10
Night exteriors lend themselves excellently to "Source" lighting. In this scene from Chaplin's "City Lights" the apparent source is the street lamp.

Fig. 11
The intense drama of "The Case of Sgt. Grischa" is noticeably aided by the strong lighting of this night exterior.

Fig. 12
This scene from "Sunrise" was lit entirely with arcs and mercury-vapor tube overhead units and illustrates model lighting for a cafe scene

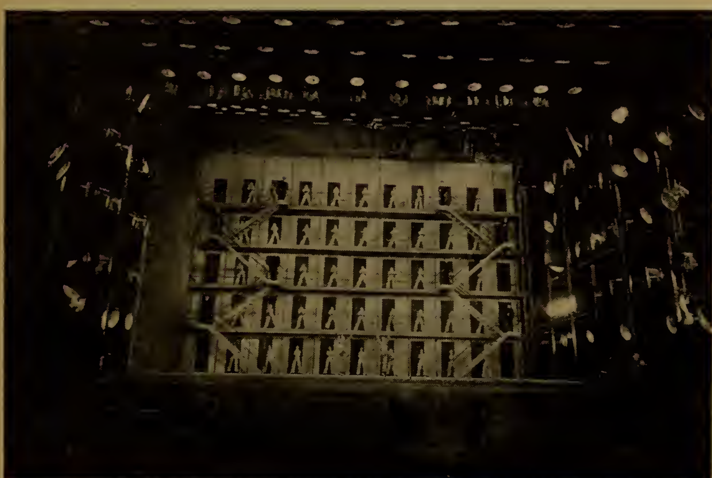

Fig. 13
In a stage scene, like this from "The March of Time," the lighting is entirely from above and in front, to stimulate the conventional stage lighting.

Fig. 14
This scene from "Shanghai Lady" is illuminated entirely with incandescent equipment.

Fig. 15
Natural color cinematography demands much light. Notice the unusual amount of front light used for this Technicolor scene from "The King of Jazz."

Fig. 16
The sombre lighting of this scene from "Lummox" is in perfect harmony with the heavy drama of the story.

Fig. 17
The bold contrasts in the lighting of this scene from "Alibi" add tremendously to the melodramatic "punch" of the action.

Fig. 18
All types of equipment—arcs, incandescents and vapor-tubes—are used to light this scene from "Paramount on Parade." Notice increase of light needed for color photography on even a small set.

Fig. 19
The contrast between the happiness of the two women and the drabness of the setting is brought out almost wholly by the contrasted lighting in this scene from "Lummox."

FIG. 20

Some of the complications introduced by sound. Note how little space there is for floor lighting equipment after placing camera booths for this scene from "Courage.

himself able to duplicate his modelling effects outside as well as in. Hard light, soft light, front light, back light, cross light, and rim light can all be supplied by properly-used reflectors—if the sun is on the job. But, even in California there are clouds, and the sun cannot be prevented from moving around the sky, and rising and setting; so, since the production staffs number no Joshuas (though they include many miracle workers), the next step is to bring the lights from the studio to supplement sunlight, and even to replace it completely on dull days. To this writer's mind, this is by far the wisest course even on bright days, for it gives the cinematographer—particularly in conjunction with the various methods heretofore outlined—as complete control of lighting conditions outdoors as he enjoys within. Furthermore, such 'booster' lights are far more efficient than reflectors and diffusers, for they are more quickly and positively operated, and, in the case of incandescent lights, are far easier for the actors to look into than are reflectors. Therefore, since most production managers are willing to send their units out with booster light equipment, it is always an excellent idea for the cinematographer in charge to avail himself of it, if for nothing else than the assurance of perfect, unfailing results, and longer, uninterrupted working hours.

But all exterior scenes cannot be made during the daylight hours; many times the script will call for sequences taking place at night.

Fig. 21
Night scenes may be made in a modestly high key, like this scene from "Sunny Side Up," if action logically permits.

In the old days, these scenes were photographed by day, but under-exposed, and printed on blue-tinted film. This was all right in its way, but today, with the abundance of lighting equipment available, and the ever-increasing cry for realism, the great majority of night scenes are actually photographed at night. Aside from the natural inconvenience it usually causes the production personnel, this is a great advantage, for it permits the cinematographer to control the light on his exterior scenes to the very smallest degree, just as he does his interiors. Together with the lighting of an interior set, this represents the highest point of artistic cinematography, for it gives the cinematographer absolute control of every bit of light reflected from his settings and characters. Then, outdoors as well as in, he can use light and shade to their fullest extent in painting the pictures he wants.

Of course the lighting of a modern set, interior or exterior, has become a highly complicated task, particularly with the vogue of multiple cameras, and the modern technique of the moving camera, which makes the camera perform literally acrobatic feats in the course of

Fig. 22
Shows workings of a night shot placing the lights and cameras for a night scene in "Mammy."

Fig. 23
"Booster" lights being used to aid natural light in scene from "The Bishop Murder Case."

following the actors around, over, and through the sets. All of this has resulted in a tremendous multiplication of the number of lighting units employed: but if the cinematographer can so train his perceptions that, like the great musicians who are so music-conscious that they are able to "hear" music as they read it—even in the complicated score of the symphony orchestra—the cinematographer can become "light-conscious", and visualize the effect of the light before him upon the sensitive film he is about to expose, then he can truly say that he is a master of the new and difficult art of cinematographic lighting.

Fig. 24
An unusual example of lighting for an air raid exterior night scene from "Hell's Angels."

SENSITOMETRY

Its History and Present Day Application in the Motion Picture Industry

*Emery Huse**

I

BEFORE entering into a discussion of sensitometry it would be well first to go back quite a few years and call to mind the beginnings of photography, in which sensitometry plays a part.

Although it was first observed in the early part of the eighteenth century that silver salts were darkened by light, no real use was made of these findings for the purpose of making pictures until Wedgewood published a paper entitled "An Account of a Method of Copying Paintings on Glass and on Making Profiles by the Agency of Light upon Nitrate of Silver." This paper appeared in the year 1802. Wedgewood conceived the idea of making silhouettes by using paper treated with silver nitrate which would darken in the light. Also Wedgewood was one of the first to try to take photographs in the "camera obscura." The camera obscura was nothing more than a camera consisting of a box with a lens at one end and a ground glass at the other. Wedgewood, of course, removed the ground glass and put his prepared paper in its place but did not achieve any great success due to the low sensitivity of his material.

Later Sir Humphrey Davey succeeded in making photographs by sunlight with the aid of a microscope. It is generally conceded that this method of Davey's gave the first pictures made by means of a lens on a photographic material.

It was quite some time later before development, as we now know of it, and fixation were discovered. This work was advanced considerably by Fox Talbot in the middle of the nineteenth century and his work was succeeded later by the wet collodion process, which is still in existence and is used by photo engravers.

The difficulties of the wet collodion plates disappeared with the coming of the gelatin emulsion process. The first gelatin emulsions were made in 1871 by Dr. Maddox. Naturally, further experimentation was carried on in the succeeding years until during the latter part of the nineteenth century George Eastman's continual experiments to substitute a light, flexible support for the heavy and easily damaged glass were successful and film as we know it today became a reality. Eastman's experiments, in conjunction with Thomas Edison, paved the way for the present day cinematography.

II

The Beginnings of Sensitometry

Sensitometry literally means a measure of sensitivity. As early as 1848 Claudet devised an instrument for determining the speed of the daguerreotype plate, which instrument was termed a "photo-

* (West Coast Division, Motion Picture Film Department, Eastman Kodak Company)

the daguerreotype plate, which instrument was termed a "photograph meter." By the aid of this meter one was able to determine the exposure necessary to produce a visible impression on the sensitive material. This method was extremely crude and was not very reliable but it no doubt laid the foundations for the work which was carried on some years later by two men in England, Hurter and Driffield, who were amateur photographers, but whose prime interest in photography was the production of images which were true to nature. In January 1891 Ferdinand Hurter states in the opening sentence of his paper "The Action of Light on the Sensitive Film" that "the function of photography is the production of permanent images of material objects as true to nature as possible." Hurter's use of the words "sensitive film" must not be taken literally as he used the word film to represent that layer of sensitive material which was coated on a glass plate.

Ferdinand Hurter was a Swiss who began the study of chemistry at an early age, which later led him to be apprenticed to a dyer, in which practical field of chemistry he achieved notable success. He went to England some years later where he eventually became chief chemist and technical adviser of the United Alkali Company.

Vero C. Driffield, an Englishman, though intending to become an engineer, became interested in the practice of photography. His engineering studies, however, led him eventually to join the same firm with which Hurter was connected and the two men became great friends. Hurter acquired his interest in photography due to Driffield's continual experiments in this general field and for several years these two men worked together in an attempt to study the underlying principles of the action of light on a light sensitive material. It must be remembered that at this time the collodion plate was practically the only sensitive material at the disposal of the photographer. It was known generally that the photographer had to expose his plate to suit the light and great difficulty was experienced in the early stages of photography in the estimation of the correct exposure. Naturally there was much guess work connected with photography of that day. Hurter and Driffield's first problem as they saw it was to devise some means of accurately measuring the actinic power of daylight. This work led to the discovery of their actinometer, data on which is incorporated in a specification drawn up by Hurter on the 23rd of April, 1881. For several years the attention of these two men was absorbed by the general subject of actinometers.

In May 1890 the first joint work of Hurter and Driffield was published under the title "Photochemical Investigations and a New Method of Determination of the Sensitiveness of Photographic Plates." This paper led to a discussion of negative density, opacity, and transparency; means of measuring densities; study of development; gradation, which was referred to by these men as the "ratio of the densities;" intensification and reduction; ending finally with speed determination of sensitive plates.

It was Hurter and Driffield who devised the means of graphically showing the action of light on a photographic emulsion by plotting density produced on a negative against the exposure causing these densities. This constitutes the origin of the so-called H and D curve, which letters refer specifically, of course, to Hurter and Driffield.

During the course of their experimental work they found it vitally necessary to evolve some means of registering a series of exposures in some form other than a heterogeneous mass of silver as is repre-

Fig. 1

sented in a picture. They needed uniformly exposed areas in order that they might determine the density of the silver produced by known values of exposure. To accomplish this they devised the first instrument of the type which we now refer to as a sensitometer. This consisted of a light source which was a standard spermaceti candle, a revolving sector disk and a dark slide containing a strip of plate of which the characteristic curve was to be determined. The position of the dark slide was behind the sector disk while the candle was placed at some distance in front of that disk. The disk had cut out of it definite angular apertures, the first opening of which was 180° produced by cutting out segments in two quadrants of the circle; the next opening had an angular aperture of 90°, or one quadrant; the next of 45°; the next 22½°, and so on, the angular aperture of each successive opening being halved until nine openings were reached. A diagram of the original Hurter and Driffield sector wheel is shown in Figure 1.

Later on this sensitometer was remodelled and consisted of a rectangular box about three feet long at one end of which was a lamp house which contained a burner using pentane gas. The other end of the box contained the sector wheel and a slot to receive a plate holder in which strips of the unexposed plate were placed for exposure. The exposure was actually accomplished by removing the dark slide of the plate holder and by mechanical means revolving the disk which was in front of it. As aforestated, the disk contained nine angular openings, decreasing by a factor two from the maximum opening of 180°. This gave an exposed sensitometric strip, which in present day parlance we would refer to as "an exposure of nine power of two steps."

The next step in their procedure was the development of the exposed plate. Up to this we have not discussed the researches of Hurter and Driffield as regards development. It will suffice to say that prior to their investigations pyrogallic acid was found to be a reducing agent for light struck salts of silver, especially the nitrate salt. The developer itself was made up of pyrogallic acid, ammonia, and ammonium bromide. Later experiments showed the use of a ferrous oxalate developer. It is interesting to note that they made investigations of varying amounts of chemical constituents used and in Table 1 is given the formula for one of the many developers made up by them.

TABLE I

Developer, 100 cc contain

0.085 g. of NH3
0.400 pyrogallol
0.250 NH4 Br.

A formula for a ferrous oxalate formula is given below as a matter of interest.

Solution A	
Potassium Oxalate	750 grams
Water to	2250 ccs
Solution B	
Ferrous Sulfate	250 grams
Sulfuric Acid 10%	15 ccs
Water to make	750 ccs
For use: 1:1	

After the development of the exposed plate the next necessary step involved the measurement of the density which resulted from the exposure and development. For that purpose Hurter and Driffield devised another instrument which was in reality a grease spot photometer. Figure II shows a sketch of the small chamber containing the grease spot and also the position of the two comparison light sources S1 and S2. The grease spot is inserted through a slit in the upper side of the chamber in the center of the instrument and its position is shown in the figure. The box containing the grease spot slides along a track and is fitted with an eye piece through which light from the two sources can be viewed as two distinctly different fields. The density to be measured is placed over one source of light and the grease spot chamber moved toward that side of the instrument until a balance is obtained by the two brightnesses. By proper calibration it was possible with this instrument to make readings in terms of density. It might be well to state here that density is defined as follows: $D = \log_{10} O = \log_{10} \frac{1}{T}$ where O represents opacity and T transmission.

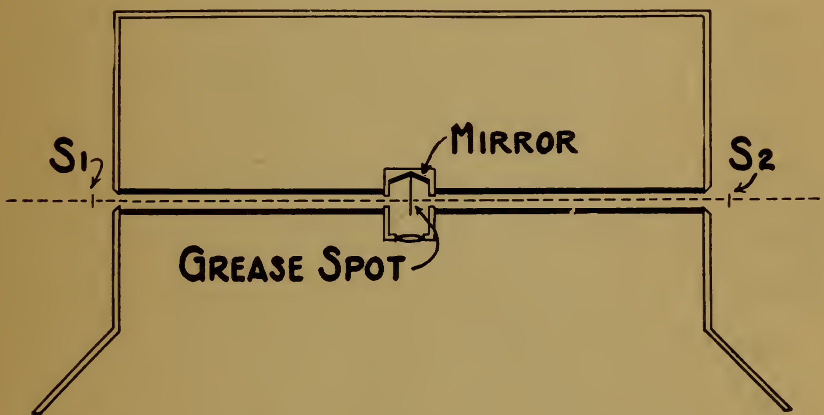

Fig. 2

With the completion of the measurements of the densities on the test strip the next step was to construct a curve showing the relationship between density and the logarithms of exposure which cause these densities. Figure III shows a curve typical of the type obtained by Hurter and Driffield. The sector wheel, as previously stated, contained nine openings, which increased by a ratio of 2. In other words, the exposures increased in that ratio. As above defined, density is a logarithmic function. Therefore, it was advisable to plot the logarithm of the exposures inasmuch as it would be difficult to plot strips covering the exposure range in straight exposure units. The following tabulation shows the relative exposure values produced by the sector wheel together with the logarithmic values of these exposures.

Step Number	Relative Exposure	Log. Relative Exposure
1	1	0.00
2	2	0.30
3	4	0.60
4	8	0.90
5	16	1.20
6	32	1.50
7	64	1.80
8	128	2.10
9	256	2.40

Using these values of log exposure the densities of the various deposits are plotted and the curve obtained. This curve is divided into three major sections as marked off in Figure III. The first section is the region of under exposure and shows a gradually increasing slope.

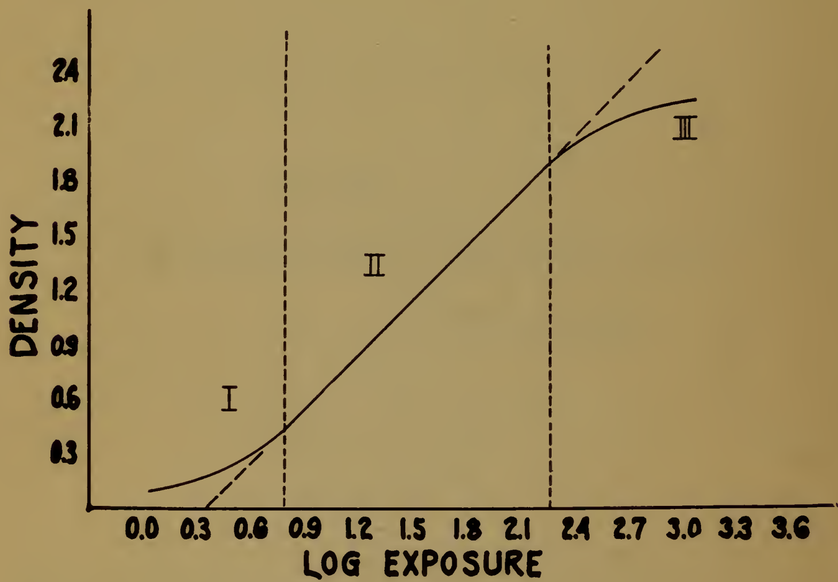

Fig. 3

The second section is the region of correct exposure and shows a straight line characteristic indicating the density is increasing proportionately with increased exposure. The third section is the region of over exposure and shows a curvature of gradually decreasing slope. From curves of this type Hurter and Driffield propounded certain definite constants, such constants as speed, latitude, development factor (gamma) were determined.

Speed was defined as the inverse of the inertia times a constant factor of 34. For example, if the inertia was considered as 0.54 the speed of the plate would be 1/0.54x34, which would equal 63 approximately. This constant was arbitrarily chosen to give speed values in whole numbers, that is, numbers greater than one.

Latitude of exposure is usually expressed in exposure units obtained by projecting the straight line portion onto the exposure axis. From the curve in Figure III the limits of the straight line portion are determined by the dotted lines appearing vertically on the curve.

The development factor, or gamma, is determined by measuring the slope of the straight line portion of the curve, considering the exposure axis as the base. Mathematically it is the tangent of the angle formed by the intersection of the straight line portion of the curve and the exposure axis. Gamma, therefore, represents the development factor and is a measure of the degree of development of a photographic material.

III

Applications of the Hurter and Driffield System of Sensitometry up to the Advent of Sound Photography

Since Hurter and Driffield's time most of the applications of sensitometry have been applied by manufacturers of photographic materials. The early plate manufacturers of England used the Hurter and Driffield system for plate speed determinations, which were used as a means of advertisement. However, these same photographic concerns were entering into an era of scientific research and began to use the Hurter and Driffield system to make a truthful study of the behavior of any type of photographic emulsions to light. Developers also were studied and it was not long before decided advances had been made toward the correct photographic reproduction of objects as they appeared in nature. In 1912 the Eastman Kodak Company in this country established, as part of its photographic manufacturing concern, a research laboratory designed primarily to study scientifically photographic problems both from the standpoint of the betterment of the photographic materials and also from the standpoint of the correct usage of these materials. For the last eighteen years therefore, this research laboratory has contributed more toward the advancement of photographic knowledge than any other single agency in the world. Such organizations as the United States Government in their Bureau of Standards have departments devoted to the scientific study of photography. Practically all of the physics departments of the leading universities, both in this country and abroad, have courses in photography.

The production of motion pictures was started in the last few years of the nineteenth century but it was not until we were several years into the twentieth century, 1903 to be exact, that the motion picture became a commercial proposition. In that year the first story to be depicted by motion pictures was "The Great Train Robbery." That picture was extremely short but really gave birth to the production of motion pictures as we now know them. It is rather safe to say that from that time to the year 1928 very little attention was given to the application of sensitometry in the production of motion pictures. Sensitometry was applied, but not as sensitometry. Light reaction of course was studied. Photographic emulsions were greatly improved. Lens design advanced also and in 1928 the motion picture as an art reached an extremely high level. For a few years prior to 1928 sound motion pictures had their beginning and two large producing companies were actually making talking motion pictures. One of these concerns accomplished their purpose by making a photographic record of their sound impulses on a wax disk following the manner employed by the phonograph companies. The other concern used the method of photographing on the negative film along with the picture a sound record which was impressed by fluctuations of the brightness of a lamp, which fluctuations were caused by changes in the electric circuit of that lamp. These changes were in turn caused by sound waves picked up by a microphone.

IV

Sensitometry as Now Practiced in the Motion Picture Industry

It is interesting to note that although in 1926 when the first commercially successful talking pictures were made, sensitometry had not yet been given any consideration. This no doubt was due to the fact that these first talking pictures accomplished their sound by the use of a wax disk. However, experiments being conducted by another of the large producing companies in an effort to produce sound records on film, were gradually becoming successful and early in 1927 the first news reel in sound appeared. During the year 1928 the motion picture industry threw off the yoke of silent pictures and became definitely involved in the contemplation and production of talking pictures.

In April 1928 the Society of Motion Picture Engineers held one of their semi-annual meetings in Hollywood. The programs of that meeting contained very few papers which pertained to the production of sound motion pictures. There were papers presented however, which led up to work of this nature. Quite definitely there were no papers read involving the photographic procedure such as is now employed in the control of making sound records on film. It was during the discussion following a paper on the general subject of machine development of film that sensitometry as a means of control of development was first discussed with the idea of its practical application. Questions arose as to the means of checking the degree of development produced in the development machine under different conditions. This discussion was rather long but it definitely planted a new idea in the minds of those people engaged in the laboratory procedure. Precise information pertaining to the Hurter and Driffield system of sensitometry was sought and after this information was gathered definite steps were made toward making use of it commercially. At the present time, April, 1930, every laboratory and studio producing talking motion pictures makes practical use of the Hurter and Driffield system.

The foregoing gives a short historical resumé of the rapid growth of interest in the application of sensitometry. It must not be construed however, that it has been only since 1928 that thought was given to practical sensitometric applications. Photographic literature is full of articles dealing with this subject and the above statement applies only to the applications of sensitometry to motion picture production problems. An endeavor will now be made to be more specific and outline how sensitometry is applied in actual picture production.

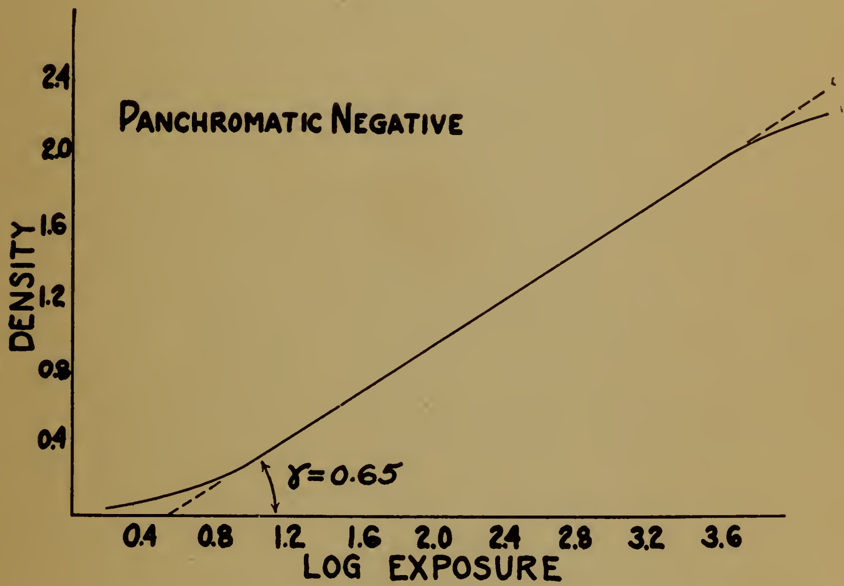

Fig. 4

A
Development of Picture Negative

The procedure followed in the determination of the extent of development of a picture negative involves a sensitometric exposure on the same emulsion used for the picture. There are several means of accomplishing this exposure. Many of the laboratories make their sensitometric strips using a light testing machine, such as are commercially obtainable. Others use a sensitometer as supplied by one of the large sound equipment companies, while others use sensitometric strips which have been exposed in a time-scale sensitometer. These exposed strips are then attached to the rolls of film to be developed, so that they receive the same development that the picture receives. At the completion of the development process the sensitometric strip is detached from the roll, the densities of the various deposits measured and its H and D curve plotted. From this curve the degree of development, gamma, is determined. This value gives a numerical expression of the degree of development. Figure IV shows an H and D curve which resulted from the exposure in a sensitometer of panchromatic negative film which was developed in a machine in one of the laboratories in Hollywood. The slope of the straight line portion of this curve gives the measure of the degree of development. This slope, as aforestated, is expressed mathematically as the tangent of the angle formed by the intersection of the straight line portion of the H and D curve with the log exposure axis.

Let us suppose now that we understand the procedure by which the degree of development may be ascertained and let us further assume that we want to check up on the degree of development on a definite emulsion number of film, in a stated developer, throughout a night's work. We shall furthermore assume that this development will be carried out in a developing machine. The procedure to be followed first necessitates the exposure of, let us say, a dozen sensitometric strips, all of which have had exactly the same exposure condition imposed upon them. At the beginning of the night's work and attached to the first roll going through the machine is one of these sensitometric strips. At stated intervals, say every 5000 ft., another of these exposed strips will be sent through the machine. This procedure is carried out at 5000 ft. intervals for the complete night's run. At the end of the night's work all of the various sensitometric strips, properly labeled as to the period during the night they were developed, are assembled, their densities read, and their curves plotted. From each strip gamma is determined and it is then possible to make a study of gamma in comparison with the film footage put through the developer. This procedure carried out for several nights and for several different mixtures of the same type of developer, leads to a rather conclusive figure as to the degree of contrast (gamma) that is being obtained for picture negatives.

It might be interesting to state at this point that a survey of the various laboratories in and around Hollywood leads to the conclusion that the average picture gamma arrived at is in the neighborhood of 0.68. This, of course, is the average of all laboratories. It is, furthermore, interesting to note that the departure from this average is not great. There is one unit which works at a somewhat lower gamma than the average, their gamma being approximately 0.55. There is another unit producing a somewhat more contrasty negative than the average and it is found that this unit works at a gamma value of approximately 0.80. Of course, considering the magnitude of difference between the low and the high values as stated, it would seem that there is an appreciable difference in the type of negative generally produced. However, inasmuch as the negative development in ten laboratories was studied and the average of all was 0.68, it means that many of them must be producing negatives relatively close to this mean value. These differences in negative contrast are naturally later compensated for by the degree of positive contrast desired by the individual producing companies. It is not amiss to state here therefore, that the average value of negative gamma combined with the proper positive gamma is productive of very high quality photographic results.

It might be well to state here that there are definite reasons for the actual magnitude of negative and positive gammas. Negative emulsions generally are of high speed and low contrast and gammas of the order of 0.65 are normal for the present day type of negative emulsions when developed in the present day negative developers. In other words, in working at gammas of this value we are working in the normal range of the film. In considering positive film we have an emulsion of an entirely different sensitivity characteristic than in the case of negative. This emulsion is normally of high contrast and slow speed. When used at gamma values in the neighborhood of 1.80 to 2.00 it is working in its normal region. These statements are made with the idea in mind that possibly the mental question would be asked, why are positive and negative gammas limited to the values as quoted.

It is important at this point to state a condition which exists as regards negative in the various laboratories, which is somewhat unique when we consider the present day practices as compared with the practices of five years ago. Reference is made particularly to the type of negative developer. Almost without exception the so-called "borax type" developer is used. Prior to the issuance of the borax formula each individual laboratory had its own "pet" negative formula. These various formulas agreed only in that they contained similar chemicals, although compounded quite differently. At the present time, however, the general practice is to use the original borax formula modified slightly to accomodate the requirements of each laboratory. Naturally, the strength of the formula used in a developing machine is somewhat less than that used for the rank and tank type of development. The point to be emphasized however, is the fact that practically all of the laboratories are using the borax formula with the constituents recommended and with the proportions of the various chemicals in a nearly constant ratio. This formula is tabulated here.

Formula D-76

Elon	120 grains
Sodium Sulphite (E. K. Co.)	14 ounces
Hydroquinone	300 grains
Borax	120 grains
Water	128 ounces 1 gallon

Temperature of developer 65°F

The name "borax developer," of course, is somewhat of a misnomer inasmuch as the borax is only an alkali and is substituted in place of the usual carbonate in the developer. Along with the borax is added several times as much sulphite as was heretofore used in developers. These two constituents together with the two developing agents, elon and hydroquinone, make up the elements of that developer. It might be stated here that the agent in this developer playing the greatest part is the sulphite. This developer is also referred to as the "fine grain developer" and it is the sulphite which is doing the work toward the accomplishment of this purpose. It is well known, chemically, that sulphite in excess acts as a partial solvent to the developing of silver halides.

When a sensitometric study is made of modifications of the borax developer, and by modifications is meant a change in the quantities of the chemical constituents of that developer, it will be observed, upon a study of the time of development—gamma relationship, that there is very little difference in the general shape of this curve. Changing the amounts of the constituents of that developer primarily do nothing more than change the rate of development, which means that these modifications will enable a laboratory to produce its specific and desired negative gamma in certain stated times of development which appeal particularly to the individual laboratories. It is found by experiment and observation that several laboratories obtaining negative gamma in the neighborhood of 0.68 arrive at this gamma in the same type of developer, that is, the borax type, in times of development which vary from 8½ to 12 minutes, however, the ultimate result is practically the same.

B

Development of Picture Positive

In giving consideration to the development of the picture positive thought must be given to the extent of development, or gamma, of the negative that is to be printed. It is desirable pictorially to have on the screen not only a faithful reproduction of the scenes taken, but an added artistic quality which enhances the beauty of the picture. Brilliant pictures are generally desired and it is found that positive gammas in the neighborhood of 1.80 to 2.00 produce a very pleasing effect in working from negatives having a gamma of 0.65. Some producing companies object to the overall contrast which is obtained in developing their positive to a gamma of 2.00 and many accomplish their desired result by developing to gammas of lesser value, oftentimes in the neighborhood of 1.80. Prior to sound photography it is rather safe to assume that the more contrasty type of picture was desired and the value of 2.00, as stated, is not exaggerated. However, it so happened that at the beginning of sound photography photographic quality had changed somewhat and generally softer final pictures were being seen on the screen. Of course changes in types of emulsions, both negative and positive, had some little bearing on this, but the greatest cause was due to the fact that great use was being made of diffusion disks and soft focus lenses. With sound accompanying the pictures the soft type of picture which was being produced did not appear satisfactory. Every endeavor was made toward clear cut sound recordings and a soft picture did not fit in with the sound recording. As a result much of the diffusion disk work was discontinued and not only different negatives but different positives somewhat more clear cut but at the same time relatively soft, more precisely to match up with the sound quality, were being obtained. It is safe to assume that at the present time the motion picture producing companies are working at positive gammas varying within the range of 1.80 to 2.00. There are, of course, individual units working low, with other individual units working high, but the average of all would not be far from positive gammas of 1.90.

A sensitometric study for positive gamma determinations and for studies of positive developers are carried out in a manner identical

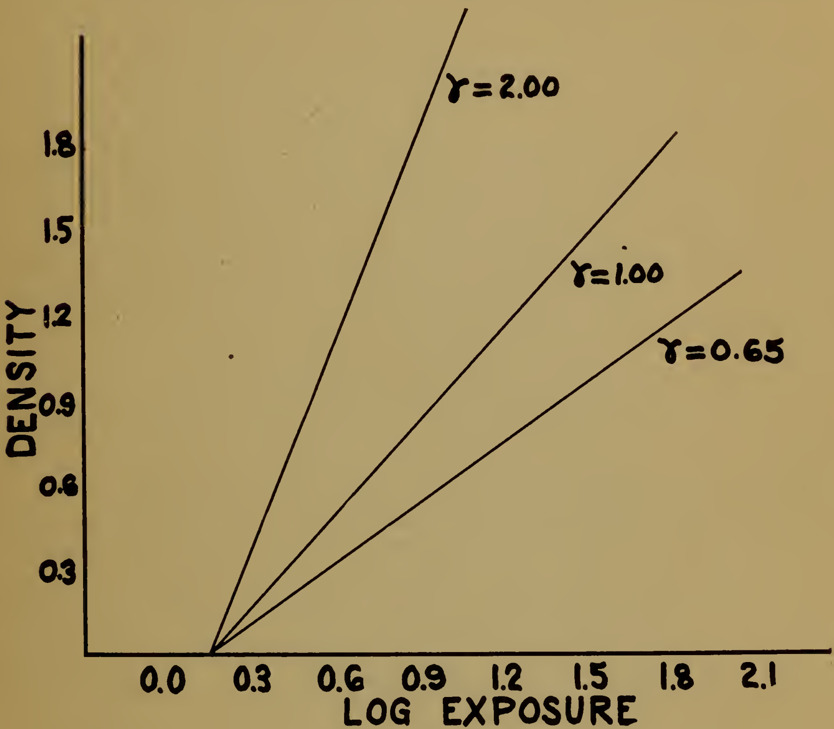

Fig. 5

to that described under the section of "Development of Picture Negative."

As regards positive developers, the condition of formulas is relatively unchanged, each laboratory works on a positive formula which satisfies the requirements of the producers by whom they are employed. Naturally, the chemicals used are quite generally the same but the proportions, the number of chemical elements, and even the choice of chemical elements, is not nearly as uniform between the various laboratories as it is in the case of the negative developers. It is possible to produce positive prints at a given gamma value in two differently constituted developers which will look quite different on the screen. However, it is always necessary to take into consideration the negative quality and the positive resulting from that negative to satisfy the requirements of the producing units.

C

Development of Sound Negative and Positive

It is under this general heading that sensitometry has made the greatest progress and taken its rightful place in the motion picture industry. It is quite probable that 90% of the sensitometry practiced pertains to the production of sound negatives and positives.

It would be well at this point to depart for a moment from the consideration of the development of a sound negative for a short sensitometric interlude. It has previously been stated that gamma is the tangent of the angle formed by the straight line portion of the H and D curve and the exposure axis. Mathmatically the tangents of various angles expressed in degrees are numerical values greater or less than unity as the angle formed is greater or less than 45°. The tangent of an angle of 45° is 1.00. When gamma values of the order of 0.65 are referred to it is easy to picture that the angle formed by the straight line of the H and D curve and the exposure axis is less than 45°. When gamma values of 2.0 are referred to it is likewise easy to picture an angle of greater than 45°. In Figure V are shown the straight line portions only of three hypothetical sensitometric curves. The gamma values of these straight lines are 0.65, 1.00, and 2.00. It will be observed that the gamma of 1.00 straight line shows equal changes in both density and exposure. In the case of the line representing gamma of 0.65 it will be observed that to produce a given density change an appreciably greater exposure difference must be given. Conversely, to produce a given density change on the gamma of 2.00 line, much less change must be made in the exposure. It therefore follows that if a piece of film is developed to a gamma of 1.00 the changes in density will be directly proportional to the changes in exposure. In other words, equal increments are obtained on both axes. It would seem logical therefore, that if a negative could be produced in which the ratio between exposure and density was unity an ideal condition would be obtained. With this point in mind, consideration can now be given to the production of photographic sound negative records.

It has been proved from a consideration of sound waves in conjunction with the exposure and development of light impulses which have been recorded on film, that the development of the negative sound track exposure would be ideal at a gamma of 1.00. Therefore, if the photographic material on which the sound record has been made is developed to a gamma of 1.00 there will then be obtained a series of densities, if a variable density method is considered, which are directly proportional to the exposures which caused these densities. Also the sound wave which has a definite sinusoidal characteristic will not be distorted if this negative is played back in a reproducer. Therefore, it would seem that if this negative were then printed and that print developed also to a gamma of 1.00, a positive would then be obtained which would upon sound reproduction, likewise, reproduce the sound impulses undistorted.

Again it is necessary to consider sensitometric characteristics. It was pointed out earlier in this article that the H and D curve of an emulsion had three distinct sections, the under, the correct, and the over exposure regions. Sound records on film must, as far as possible, be restricted to the correct or straight line portion of the H and D curve. For that reason it is customary to study sensitometrically the emulsion on which sound negatives are to be exposed and the developer that has been chosen and determine the limits of the straight line portion of the curve. This is accomplished quite easily in sound recording if consideration is given, for example, to the light valve method of recording, which produces a variable density record. It is known that the ribbons of the light valve operate between certain fixed positions, that is, they close and then open to the limit of the valve. The so-called unmodulated position of the ribbons allow half as much light through them as can be put through them when they are separated to their maximum extent. Therefore, at the unmodulated position it is known that only a factor of two times greater exposure can be obtained. On the H and D curve of the emulsion being studied it is customary to place the density of the unmodulated exposure 0.3 log exposure units below the point where the over-exposure region breaks away from the straight line portion. This is done because 0.3 is a logarithmic value of exposure and a 0.3 difference in log E represents a change of a factor of 2 in exposure. Therefore, between this point and the break of the curve at either end of the straight line there remains sufficient range to record on that straight line the entire functionings of the light valve.

The condition of developing the sound negative to a gamma of 1.00 is ideal when the print can also be developed to a gamma of 1.00. If sound records only are considered this procedure is permissible, but when it is necessary to have the release print record contain both the picture and the positive sound track, gamma of unity is not sufficient to give a picture of the desired quality. Therefore, to obtain the desired picture quality it is necessary to raise the positive gamma. To do this, however, it is necessary to develop the sound negative to a gamma lower than 1.00. In other words, in the production of sound records photographically, it is desired that the product of the negative and positive gammas equal unity (1.00). It can be seen readily that a negative gamma of 1.00 and a positive gamma of 1.00 equals 1.00 when multiplied together. When the negative gamma is lowered therefore, to a value of, for example, 0.65 it is necessary to raise the positive gamma to such a value that the product of the two gammas should also equal 1.00. These results expressed numerically would be yN 0.65 x yP "X" = yO 1.00 or yP "X" = 1.54. However, as aforestated, positive gammas to produce good pictures must be higher than the 1.54 determined above. This can be accomplished by still further reducing the sound negative gamma, or better, by increasing the overall gamma to a value somewhat greater than unity. As a matter of fact overall gammas of greater than unity are obtained in actual production, as can be seen from the following example, which represents a condition followed in one of the studios. This studio works at a negative gamma of 0.65 and a positive gamma of 2.00. Therefore, expressed numerically, the results appear as follows: yN 0.65 x yP2.00=yO 1.30. It will be seen in this case that the overall gamma is appreciably higher than 1.00 but it has been found by practice that there are not sufficient distortions rendered in the sound reproduction to prohibit this procedure being followed. It may safely be stated that sound track negatives are developed relatively close in value to those obtained in the development of picture negative and the sound positive gammas are not far removed from those stated under the section "Development of Picture Positive."

In attempting to explain the sensitometric features in sound recording the discussion was confined to the variable density method of recording. However, in making sensitometric studies for the variable area system of recording it is just as necessary to know what is happening and to plan sensitometrically as it is for variable density recordings. In the case of the variable area system, however, it is

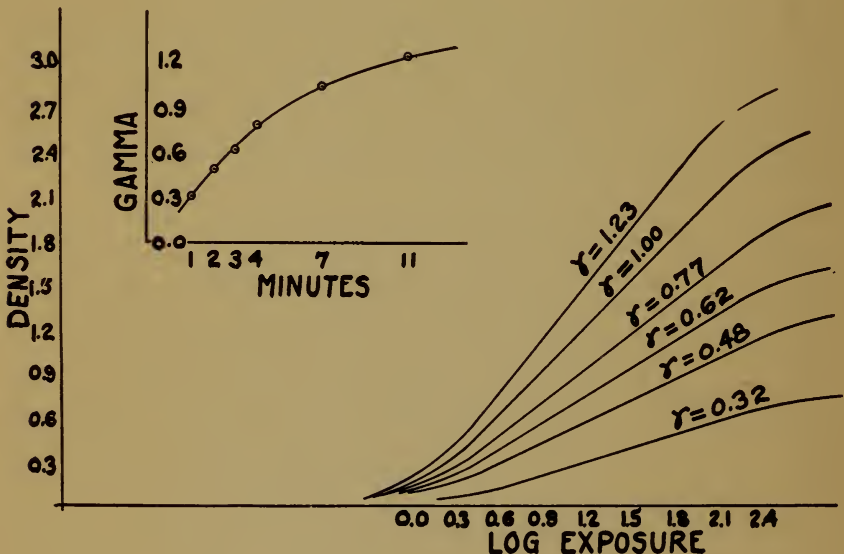

Fig. 6

necessary to produce a fixed degree of density at a predetermined gamma, the variable area sound track consisting only of a solid density and clear film base. The determination of gamma, of course, is primarily for the purpose of fixing the degree of development and with which determinations it is possible to keep the development condition constant.

In arriving at the values quoted in this article a great many sensitometric measurements were necessary. Several types of emulsions were studied. Also a given type of emulsion was tested sensitometrically in many developer formulas. These tests necessitated the making of H and D strips, measurements of density, and plotting of curves.

It is not sufficient simply to produce an H and D curve. A complete study of an emulsion or of a developer involves the developments of similarly exposed sensitometric strips for various times in a given solution. These strips, after plotting, are computed for gamma. From these gamma values, and from the times of development given, the relationship between time of development and gamma can be studied. Figure VI shows a typical series of H and D curves developed in a given developer for a series of times. Along with these curves is the gamma-time of development curve referred to above. From such a curve it is possible to determine the time of development necessary to produce any desired gamma within the range of that emulsion for that developer. Naturally, different types of emulsions in the same developer would produce curves of different shape. Also a given emulsion in various developers would produce time-gamma curves of different shape.

The facts brought out in this article only sketchily cover the subject but it is hoped that it will lead those not involved in the practical applications of sensitometry to realize the necessity of such studies. It is a fact that the practical applications of sensitometry have played a great part in the successful production of the present day high quality talking pictures and that furthermore, outside of advances in the equipment necessary to produce talking pictures, more advances will be made when sensitometry is more generally understood and practiced.

L. Guy Wilky, A. S. C.

LIGHT FILTERS AND THEIR USE IN CINEMATOGRAPHY

*Ned Van Buren, A. S. C.**

CINEMATOGRAPHY, as practiced today, differs appreciably from the cinematography of five years ago. At that time there was but one type of negative film on the market and with the light sources available this film, under those light sources and under daylight conditions, proved adequate for the needs of that time.

However, as time passed it was desirable to produce on the screen different effects which caused the observer to more completely enjoy what was being shown. The present day effects in cinematography could not be accomplished with the use of the old type regular negative film.

About three years ago panchromatic negative film was used very sparingly. One of the reasons for this was the fact that it was difficult to handle this film in development unless the complete lighting arrangement was changed. This placed a burden on the laboratory. Also, a cameraman experienced difficulties because he was up against the proposition of contrast. The earlier type panchromatic films gave more contrasty results pictorially than the regular negative. Furthermore, the cameraman was confronted with the idea that to use panchromatic negative properly it was necessary to use light filters. These difficulties did in reality exist. About two years ago, however, a new softer type of panchromatic film was put on the market, the characteristics of which were similar to regular negative, as far as contrast was concerned, but the results on which were vastly different in that a simple test proved the panchromatic film capable of color separation in the negative of objects photographed, that was not possible with the regular negative. From that time on the use of panchromatic film increased, while regular negative began to lose its foothold until at the present time panchromatic negative is used universally in the motion picture industry as the film on which the picture negative is recorded. As the cameraman became more familiar with the ability of panchromatic film to record more satisfactorily the objects photographed, it was natural that knowledge pertaining to the use of light filters was desired.

Before dealing at length with the subject of filters and their present day uses, it would be well to consider first some of the fundamental principles underlying photography, that is, the general subject of light. At the present time incandescent lamps are used to great extent indoors and of course sunlight and daylight are made use of on exteriors. Sunlight is referred to as white light. The light emitted by an incandescent lamp in which the lamp filament is tungsten is also referred to as white light. The reason for this is because by definition white light is made up of all visible colored light. It necessi-

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tates the combination of blue violet, blue, blue green, green, yellow, orange, and red, to give us white light. When an analysis of sunlight, or daylight, and tungsten is made in an instrument which has the ability of breaking the light up into its component parts, it will be observed readily that all visible colors are present. If we by some means subtract some definite color from white light we will have left a color which is no longer white, but which is a combination of the remaining colors of the spectrum. For example, if all of the red light is removed by some means from white light, we would have as a result a bluish green light which is made up of the remaining colors. Likewise, if by some means we could remove the green light from a white light, we would, as a result, have left a color which we refer to as magenta. Furthermore, if we remove the blue and blue violet from white light we have left, as a result of the combination of the remaining colors, yellow. The means of removing these sections of light from white light is accomplished by the use of light filters and if we examine light filters by looking at white light through them, we can see that the above statements are true. So far, consideration has been given only to the effect of removing visually certain bands of color from white light.

In photography, with the use of panchromatic film and filters, effectively the same results will be obtained. The human eye has a definite visibility characteristic and it is able to record all of the different wave lengths of light which are referred to as color. Naturally, only those things are colored that our eyes see colored.

Panchromatic film has had incorporated in it, by chemical means, the ability to perceive most all of the colors visible to the eye. The eye sees more of one color than it does of another but panchromatic film also has that function, although the colors in preponderance visually are not the same as those most strongly recognized by panchromatic film. In other words, the color sensitivity characteristic of the eye (visibility) has its maximum in the yellow region of the spectrum. The panchromatic negative film has its maximum sensitivity in the blue violet region of the spectrum. However, the limits of visibility and sensitivity throughout the spectrum are essentially the same for the eye and the panchromatic film. However, panchromatic film has a greater extension of sensitivity at both the blue violet and red ends of the spectrum than the eye has visibility. The point to be made, however, is that the panchromatic film and the eye are similar, although not alike.

In the use of filters the cameraman has the desire to accentuate some portions of the scene being photographed and to hold back other portions of the picture. For example, a yellow filter which has the power of absorbing blue, tends to lessen the effect of sky in a scene and produce a darker rendering of the sky in the print. It also allows for the exaggeration of cloud effects, due to the fact that much of the blue is being absorbed. This has the effect of producing, photographically, more contrast between the sky and the clouds in that sky. On the other hand, it might be desirable to render some red object in a scene lighter than it appears to the eye. This can be accomplished by using a filter which absorbs some of the blue and green region of the spectrum but allows the bulk of the red light to be transmitted.

In the group of Wratten light filters, which are used to a great extent in present day cinematography, there are relatively few of the some hundred filters available that can be used as taking filters by a cinematographer. There are the well-known K series of filters, some of the red filters, and occasionally a combination of two filters. For night effects made in the daytime deep red filters are often employed.

The panchromatic film as available today is by far the fastest, most color sensitive emulsion that manufacturers of photographic materials have yet devised. This makes the use of filters somewhat easier because to use a filter means that some light must be sacrificed and filters of high absorption cannot be used except in special cases, due to the fact that to produce an image too great an exposure is necessary. Oftentimes this increased exposure cannot be accomplished by either opening the lens or increasing the shutter opening, so that the only alternative would be to increase the time of exposure. It is highly undesirable to do this because one cannot have action in a picture, and especially in a talking picture, which has been photographed at different camera speeds.

It would be well at this point to name specifically the filters most commonly in use in the present day cinematography, giving data for each filter, referring to the type of work for which it can be used, together with that filter's multiplying factor. The multiplying factor of a filter is arrived at by either laboratory or practical test and expresses the number of times the exposure should be increased when using a filter over the exposure that was given on the same scene under the same lighting conditions and, incidentally, for the same development conditions when no filter was used. The first filters falling in this list are the K series of filters, namely, the K-1, K-1½, K-2, and K-3. These filters, taken as a group, are referred to as Orthochromatic filters. They are used when it is desired to reduce the blue light in a scene. These filters are yellow and, as aforestated, yellow absorbs blue, so that when these filters are used, only part of the blue light in the scene will be transmitted by those filters, the amount of blue light absorbed being dependent upon the destiny or the degree of yellow in the filter. For that reason these filters, from K-1 to K-3, contain more yellow dye as they increase in their number. The multiplying factors of the K filters are K-1 = 1½; K-1½ = 2; K-2 = 3; and K-3 = 4½. These values represent the average for many emulsions of the same type, that is, for many different emulsion numbers of a definite kind of film of a specific manufacture.

Added to these filters, likewise yellow in color, but showing a decided tendency toward orange, is the G filter. This filter is somewhat deeper than the K-3, the deepest of the K series, and produces slightly different results, this because of the fact that its spectral transmission characteristic is slightly different.

The multiplying factor of this filter is approximately the same as that for the K-3. It may be found that the factor will vary from

4½ to 5. It should be added that this yellow group of filters is almost invariably used on exterior shots.

Another group of filters which has possible uses in cinematography are the light red filters. These filters are known as the E filters and are occasionally used on exteriors. These filters are used sparingly and exclusively on exterior shots. The multiplying factor of the No. 23 filter (E red) is approximately 8.

There is another group of red filters which are used again exclusively on exterior shots to produce night effects in the daytime, that is, the scene is actually shot out of doors during the day, but the filtering accomplished is of such a nature that a very light negative is obtained, from which a dark print is made, which, when viewed upon the screen, gives the impression of a night scene. The A filter (No. 25) is commonly used for this work. This filter has a factor of approximately 10. Another filter, likewise deep red, is the F filter (No. 29). The multiplying factor of this filter is approximately 20. It can be seen from the value of the multiplying factor that when this factor is used, even though the lens is open and the maximum of exposure is given at normal cranking speed of the camera, a thin negative will result. However, it is not the production of the thin negative that gives the night effect, but it is the fact that this filter, and as a matter of fact all red filters are absorbing practically all of the light except the red and, therefore, only those objects in the scene which are red will be photographed to any marked degree, so that the night effect is accomplished by filtration more than by under-exposure. In using these different red filters one must bear in mind two important considerations, first, that the make-up on the actors will be rendered quite light, and second, reds and yellows will, in most cases, photograph very light, while the blues will be rendered darker.

It has been found by experience, and the author of this paper has recommended to various cameramen, that the use of a combination filter made up of a 23A and a 56 produces excellent night effects. These two filters combined give a red type filter which differs slightly from the single red filter spoken of in the preceding paragraphs. The author has found that this filter is effective for night scenes photographed in the daytime and that the filter factor of the combination is of approximately ten. This combination of filters will render make-up quite normally, while the reds and yellows are not washed out. Furthermore, the blues will show a decidedly darker rendering.

The 70 and 82 filters can likewise be used for night effects in the daytime but in the case of both of these filters increased exposure is necessary and unless hypersensitized panchromatic film is used it would be necessary to crank the camera at a lower speed. The multiplying factors of these filters are much higher than 20 and it is not considered of any value to make a statement as to their factor here. It should be stated with reference to hypersensitized film that the effect of hypersensitizing is to greatly increase the red speed of the emulsion. From that standpoint it can readily be seen that the use of filters, such as these two, would become more general. As a matter of fact, probably the best night effect scenes shot in the daytime can be obtained using hypersensitized panchromatic film and either the 70 or 72 filter.

Except for the use of neutral gray filters, the above mentioned filters constitute most of those used in present day cinematography. The use of neutral filters has been written of before. The neutral filters have the effect of non-selectively cutting down the light. Any photographer knows that the amount of light striking the film can be reduced by stopping down his lens. It is very often desirable, however, to photograph a scene with the lens relatively wide open. Without the use of neutral filters oftentimes this would produce an over-exposed negative, unless, of course, the shutter opening of the camera was changed. With the use of neutral filters, it is possible to leave the shutter fixed, open the lens to its maximum if desired, and photograph with the proper transmission neutral filter in the system. It has only been during the past year that use has been made of neutral filters when photographing directly into glaring light, that is, such light as might be reflected from white buildings and sidewalks.

It will be observed that of the filters mentioned, practically all of them were designated for exterior uses. It is not necessary, with the present type of lighting equipment, especially incandescent lights, to use any filters on interior scenes, except in the case of color photography. However, this article is not in any respect dealing with the use of filters for color photography. A comparison of scenes photographed under arc lights and also under incandescent lights, individually, shows that the incandescent light effectively produces a negative similar to one which would be produced if arc lights and a K-2 filter were used. It is quite generally agreed that the incandescent light, in terms of the arc light, has a filtering quality of approximately a K-2 filter. This condition arises because of the difference in the quality of the light emitted by the two sources. The arc lights preponderate in blue and the effect of using a K-2 filter with an arc light would be to reduce some of the blue. The incandescent light, on the other hand, has its greatest emission in the red end of the spectrum and again the K-2 filter in conjunction with arc lights, while lowering the effective blue emission, effectively increases the red emission, so that, to repeat again, the arc lights plus a K-2 filter give a rendering on panchromatic negative similar to the incandescent tungsten lamps.

There are, of course, other filters which are used for special work, trick photography employing quite a few, but as this article is intended primarily to review the use of filters as applied to making production motion picture negatives for black and white work, any references to color photography and trick photography have been omitted.

Rainy Day William Stull, A. S. C.

BORAX DEVELOPER CHARACTERISTICS

*H. W. Moyse and D. R. White**

THIS study of borax developers was undertaken because their wide use emphasized the importance of detailed knowledge of their action. The results of the study not only permit the selection of a developer formula which seems very satisfactory, but also points out the sort of variations that will either increase or decrease the activity of the developer, to meet any special needs that may occur.

The tests were made with a number of negative materials in each development. Strips of film were exposed back of a sector wheel which gave a series of exposures varying on a time scale with factor two steps between successive areas of the strip. Strips were then developed for a number of lengths of time in the developer being tested. During this development the flat developing tray used was rocked systematically to give high, reproducible agitation which rapidly removed development products from the emulsion surfaces of the strips which were held flat at the bottom of the tray. The densities were read as diffuse densities and gave the density-time of exposure-time of development data used in comparing the developers.

To cover systematically the range of possible combinations of chemicals two series of tests were conducted. In each series one basic formula was being considered, and the test centered to some extent on that formula but in both series the variations covered a relatively wide range of concentrations. Many of these, of course, were such that they all aided in showing the relationships among and the developing effects of the constituents. Table 1 gives the two basic formulas and also indicates the range of concentrations tested.

Table 1

Chemical	*Series 1*	*Series 2*	*Range*
Sodium sulfite (Anhyd.)	100 g.	85 g.	1-200-g
Borax	2	5	0-Saturation
Metol	2	2.5	1-10
Hydroquinone	5	0	0-20
Potassium Bromide	0	0	0-2.5
Water to	1 liter	1 liter	

Results Sulfite

It was found that an increased rate of development accompanied increases in sulfite content up to a rather definite maximum, beyond which additional sulfite caused a falling off in high densities and in many cases a distinct loss in effective emulsion speed. Fig. 1 shows curves for one time of development in developers differing only in sulfite content.

The increasing development occasioned by increase of sulfite concentration from the initial low value is apparently due to the increased alkalinity produced by the larger quantities of sulfite. The

* Research Laboratories Dupont-Pathe Film Mfg. Corp.

alkalinity increases to a limiting value such that further sulfite additions leave it unchanged.

An increasing solvent action also accompanies increase of sulfite concentration. This solvent action has been known for may years and C. E. K. Mees* and C. W. Piper (I) published data on the quantities of silver bromide necessary to saturate aqueous solution

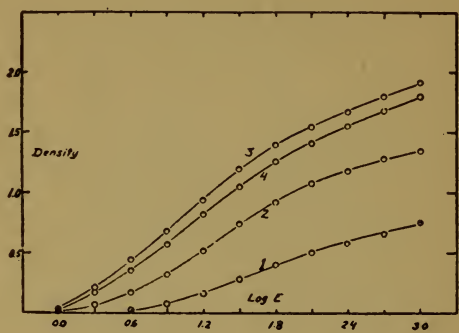

Fig. 1. Eight minute developments with: Sodium sulfite, varied; metol, 2 g/l. Hydroquinone, 5 g/l; borax 2 g/l. Emul. No. 1612.

Curve	Sulfite	Fog
1	1 (approx.)	.01
2	10	.06
3	50	.13
4	100	.14

of sodium sulfite. Under developing conditions saturation may not be reached and the rapidity of solution may be affected by the other chemicals present. To test this solvent action in developers, test series were mixed differing only in sulfite content. Equal quantities of film were developed for equal times determined. Fig. 2 shows the change of silver content with increase of sulfite concentration. The slope of this curve is increasing rapidly, showing that a markedly greater effect of the solvent action is to be expected at the higher sulfite concentrations. The actual amount of silver observed in the developer was only a small porportion of the silver on the film, so small in fact that we hope to test more fully this solvent action to see if it really is a sufficient cause for the decrease of density observed.

The two effects just cited appear to be sufficient to account for the maximum development produced with increasing sulfite concentration. At low concentrations the increased alkalinity appears to be predominant, while at high concentrations the solvent action seems more important.

Other workers have shown that high sulfite concentration tends to produce fine grained images. From a practical point of view a developer which gives a satisfactory fine grain with maximum effective emulsion speed is to be desired. A sulfite concentration of 75 grams per liter was found to give satisfactorily grain free images, and at the same time to give a high effective emulsion speed.

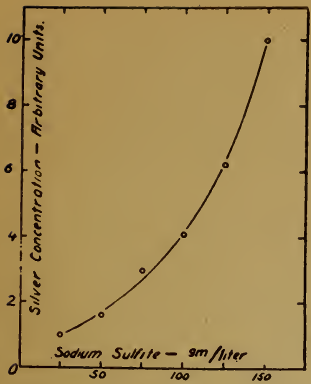

Fig. 2. Relative silver content of developers after eight minute agitated development with the equivalent of 32 ft. of film per liter. The developing formula was sodium sulfite, varied; metol, 2.5 g/1; borax, 5 g/1.

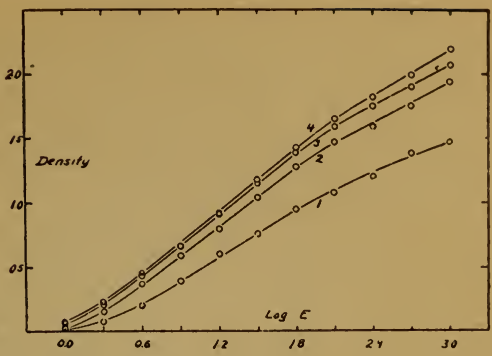

Fig. 3. Eight minute developments with: Sodium sulfite, 75 g/1; metol, 2.5 g/1; borax, varied. Emul. 2568.

Curve	Borax	pH	Fog
1	0	8.7	.03
2	2.5	8.7	.07
3	5	9.0	.07
4	10	9.1	.06

Borax

The borax appears to influence the development only through its effect on the alkalinity of the solution and hence its effect can be completely presented only in conjunction with other factors affecting the alkalinity of the developer. For the simple case, varying borax only, Fig. 3 shows the effect on the development for the 8 minute period chosen. Increasing the borax increases the alkalinity (represented by increasing pH) with a resultant increase in the activity of the developer. With the quantity of metol used in this series, there is little difference between development with 5 and 10 gm/1. of borax.

Reducers

In the first series of tests with its low borax concentration it soon became evident that the hydroquinone did little of the development. When the basic formula indicated for this series was mixed with the omission of metol, 16 minutes agitated development gave a barely perceptible density at the longest exposure given the test strip. Needless to say, such development is worthless. Mixing again, this time including the metol but omitting the hydroquinone produced a fairly satisfactory developer; one which produced densities which differed but very slightly from those produced by the complete formula.

In the case of the second series a similiar test was made, the results of which are presented in Fig. 4. Here the borax concentration is higher than in the previous case and the hydroquinone alone does develop noticeably, but still not enough to make a worth while developer by itself. Metol alone is very satisfactory and the densities differ but little from those produced with an additional 5 or 10 gm.

hydroquinone. The tests showed a tendency for fog to increase more than in proportion to the additional development produced by the increase of hydroquinone. The net result was that cleaner, more satisfactory development was obtained by increasing the time some twenty percent with metol only as a reducer. The degree of increase of fog with hydroquinone differed somewhat between emulsions, and in many cases was serious.

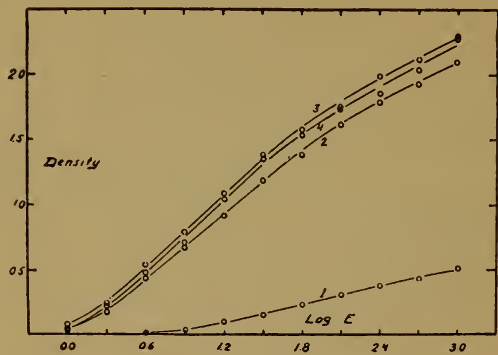

Fig. 4. Eight minute developments with: Sodium sulfite, 75 g/1; metol, varied; borax, 5 g/1; hydroquinone, varied. Emul. 2568.

Curve No.	Metol	Hydroquinone	Fog
1	0	20	.07
2	2.5	0	.07
3	2.5	5	.08
4	2.5	10	.10

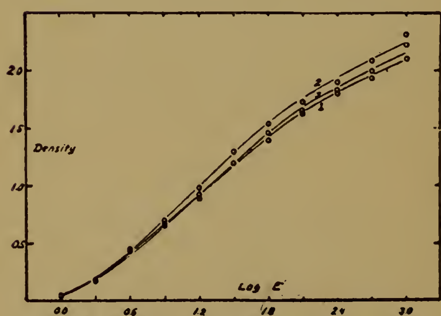

Fig. 5. Eight minute developments with: Sodium sulfite, 75 g/1; metol, varied; borax 5 g/1. Emul. 2568.

Curve No.	Metol	pH	Fog
1	2.5	9.0	.07
2	5	8.6	.05
3	10	8.2	.07

With metol alone as a reducer, the image density for fixed time of development does not increase indefinitely. Fig. 5 shows a series of curves with increasing metol concentration. It is to be noted that the alkalinity of the developer, pH, decreases due to the addition of the metol, which is sold commercially as a sulfate and hydrolyzes liberating acid in the developer, making the solution less alkaline.

The activity is thus so reduced that 10 g/l. of metol gives less development than 5 g/l. The increased concentration can be made

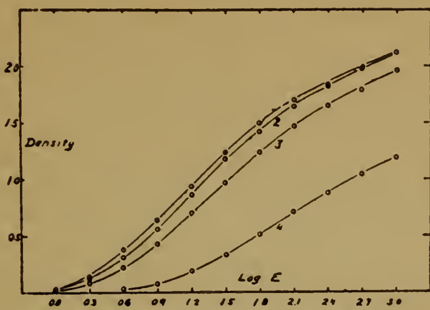

Fig. 6. Eight minute developments with: Sodium sulfite, 75 g/l; metol 2.5 g/l; borax, 5 g/l; potassium bromide, varied. Emulsion 1612.

Curve No.	Bromide	Fog
1	0	.15
2	0.1	.12
3	0.5	.08
4	2.5	.04

more effective by progressively increasing the borax content as the metol is added, if that increased activity is desired. A balance of 5 g/l. borax and 2.5 g/l. metol together with 75 g/l. of sulfite gives a developer which very closely approximates the development rate of other borax formulas in use, and at the same time makes economical use of the expensive reducing agent.

Potassium Bromide

The fog produced by this developer is sufficiently low so that no bromide is needed as a restrainer. The retarding effect of bromide is shown in Fig. 6. Even with small quantities there is a marked loss of effective emulsion speed.

The accumulation of bromide and other developer reaction products does not rapidly impair the development characteristics. Fig.

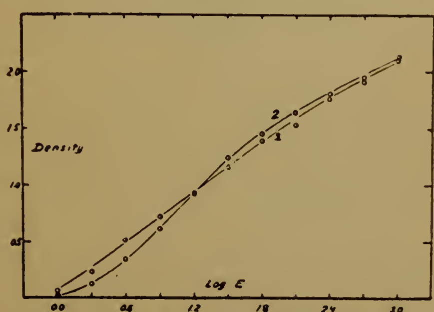

Fig. 7. Exhaustion test of the developer recommended.

Curve No.	Feet per Gal.	Time of Development of Test Strips
1	0	8 min.
2	400	12 min.

7 shows the results of an exhaustion test with this developer. It will be noted that after 400 ft. per gallon had been developed, 12 min. in the old developer and 8 min. in the fresh developer produced a density of approximately 1 for equal exposures. This longer development, however, gives pictures with slightly less shadow detail than the shorter development time gives in the fresh developer. The alkalinity of the developer under observation remained practically constant, showing that the necessary increase in developing time comes as a result of the reduction of concentration of reducer and the accumulation of bromide and reaction products in the developer rather than to alkalinity decrease. The practice of renewing a borax developing bath with additions of borax serves to bring the rate of development back to the original figure but can not bring the detail giving power which has been lost through the progressive bromide accumulations. The permissible tolerance will vary somewhat with the class of work, and will determine the "life" of the developer.

MATERIALS FOR CONSTRUCTION OF MOTION PICTURE PROCESSING APPARATUS

*J. I. Crabtree, G. E. Matthews and J. F. Ross**

WHEN selecting a material for the construction of processing apparatus, several factors should be considered, namely: (1) The resistivity of the material to the most corrosive liquid with which it will come in contact. For example, a galvanized tank, while fairly satisfactory for washing purposes, is very rapidly corroded by fixing baths.

(2) The effect of the material on the photographic properties of the solution. For instance, a developer solution in a brass tank may appear visibly unchanged, but on testing, it may fog emulsions badly, due to the presence of copper salts dissolved from the brass.

(3) The time during which the solution will be in contact with the material. If a developer is stored in a japanned tank, the japan will ultimately soften and peel off.

(4) The cost of the material.

(5) The adaptability of the material for construction purposes. Glass, for example, is entirely unsuitable for large tanks because of its fragility, and the difficulty of annealing such tanks.

There are three general classes of materials suitable for the construction of processing apparatus; metallic materials, coated metals, and non-metallic materials. These may be sub-classified as follows:

A. Metallic materials: Unplated and plated metals; alloys.

B. Coated metals: Enameled steel, asphalt-coated metals, and lacquered metals.

C. Non-metallic materials: Enameled steel, glass, impregnated fibrous materials, wood, paraffined wood, porcelain and glazed earthenware, rubber, rubber composition, and nitro-cellulose materials, slate and Alberene stone.

Metallic Materials

No metal or alloy has yet been found which will resist corrosion in all photographic solutions, and it is therefore necessary to restrict their use to specific purposes. Metallic materials possess certain very desirable properties, however, such as ductility, non-fragility, and general workability.

In considering the suitability of a particular metal for construction purposes, it is very important to know whether the article will be built of a single metal or of two or more metals. In the former case, only the corrosive effect of the solution itself need be considered, whereas in the latter case, an electrical current flows between the

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

two different metals and its effect must be considered in addition to the chemical action.

In testing the resistivity of various metallic materials to chemical action, it is necessary to observe the effects obtained under two sets of conditions, (1) those in which only a single metal or alloy is involved, and (2) those in which two or more metals or alloys are in contact with each other, and also with the photographic solutions.

Single Metals and Metallic Couples

The Resistivity of Single Metals in Photographic Solutions

An extended series of tests has been carried out to determine the resistivity of a large number of metals and alloys to common photographic solutions. The experimental details of the tests made on most of the materials given in the following list, are recorded in a paper by two of the present authors.*

Metals—Aluminum, Iron, Lead, Nickel, Tin, Zinc.

Plated Metals—Galvanized Iron, Tinned Iron, Lead-coated Iron; Aluminum-coated Iron, Chromium, Silver, and Cadmium-plated Brass.

Alloys—Allegheny Metal (chromium-nickel-steel), Aterite No. 136 (copper-zinc-nickel), Brass, Duriron, Monel, Niaco (nickel alloy), Nickel Silver (copper, zinc, nickel, iron), Nicolene (nickel-copper), Phosphor Bronze (copper-tin-phosphorus), Solder (both high and low tin content), Rezistal Steel (chromium steel), Type Metal (lead-tin-antimony), Duralumin (aluminum- magnesium-copper), Corronil (nickel alloy), Nichrome (nickel-chromium), and various stainless steels.

The Resistivity of Two or More Metals in Metallic Contact Towards Photographic Solutions

When two different metals are placed in contact and immersed in a solution, an electrolytic battery is formed which causes more or less rapid disintegration of one of the metals. This electrical action may occur in several ways; with plated metals, when some of the plating wears off; with soldered metals, between the solder and the metal; and with alloys, between the tiny crystals of the various metals which compose the alloy.

In making metal containers for photographic solutions, it is often necessary to use a second metal or alloy in the form of solder, to render joints or seams free from leaks. Also, in the construction of pipe lines for transporting solutions, it is frequently not possible to use faucets or fittings of the same material as the pipe line. A concrete example of the trouble which may arise from the metallic contact in a solution is as follows:

In the course of a series of tests on metal tanks of a copper-nickel alloy, soldered on the inside with a lead-tin solder, it was observed that if a developing solution remained in the tank for a short time the developer gave very bad fog. The solder with which the seams

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* "The Effect of Electrolysis on the Rate of Corrosion of Metals in Photographic Solutions" by J. I. Crabtree, H. A. Hartt, and E. E. Matthews, *Ind. & Eng. Chem.* 16, (1924) 13, and Corrosion of Monel Metal in Photographic Solutions" by J. I. Crabtree and G. E. Matthews, *Ind. & Chem.* 16 (1924) 671.

of the tank were soldered appeared to be slightly etched, and the original lustre of the metal had disappeared and was replaced by a dark, grainy deposit. The alloy itself was unaffected as far as could be detected from its physical appearance. A series of tests definitely proved that this excessive fog was a result of the tin constituent of the solder passing into solution, due to the flow of an electric current through the solder, the solution, and the alloy.

Corrosion was also observed due to the same cause when a tank made from this alloy and soldered on the inside was used as a container for an acid fixing bath, except that the alloy was corroded instead of the solder. When the joints were soldered on the outside, no developer fog was produced and corrosion was considerably less.

An extended study of this aspect of corrosion has been made and the results are given in two papers.*

Value of Various Metallic Materials

Only the practical application of the results of tests on the various metals will be considered in this article; the orginal papers should be consulted for more detailed information.

Metals

Lead and nickel were the only metals tested which appeared to be of any especial importance for use with processing solutions although iron is of value for particular purposes. Lead, nickel, and iron (black or ungalvanized) tanks or piping can be satisfactorily used for most developing solutions although lead is attacked by strongly alkaline developers. Chemical lead is more resistant and is to be preferred to ordinary lead.** Tanks lined with lead or nickel can be used for fixing solutions but they are slowly attacked, become coated with silver, and must eventually be replaced.

Plated Metals

Galvanized iron has long been used for the manufacture of washing tanks although it is not entirely suitable for this purpose. Vessels made of this material must not be used for mixing developers which contain sodium bisulfite, because the bisulfite attacks the zinc coating, forming sodium hydrosulfite which causes fog.***

Nickel plated brass is satisfactory for small developing tanks which are used intermittently. Metals plated with silver, either by deposition from an exhausted fixing bath, or by electroplating are more resistant to developing solutions according to the homogeneity of the silver coating, but their resistance towards fixing baths is only slightly greater than that of the unplated metals. Aluminum and cadmium coated metals do not satisfactorily resist photographic solutions. Chromium plated metals would probably be satisfactory if it were possible to secure a continuous non-porous coating over the base metal, but no such coatings are available to date. Lead coated iron can

* "The Effect of Electrolysis on the Rate of Corrosion of Metals in Photographic Solutions" by J. I. Crabtree, H. A. Hartt, and G. E. Matthews. *Ind. & Eng. Chem.* 16, (1924) 13, and "Corrosion of Monel Metal in Photographic Solutions" by J. I. Crabtree and G. E. Matthews. *Ind. & Chem.* 16 (1924) 671.

** Obtainable from National Lead Company, 111 Broadway, New York, N. Y. Branches in all large cities.

*** "The Fogging Properties of Developing Solutions Stored in Contact with Various Metals and Alloys," by J. F. Ross and J. I. Crabtree. *Amer. Phot.* 23, (1929) 254.

be used for developing and washing tanks if the iron base-metal is not exposed, but is not very satisfactory.

Plated metals and alloys are always open to the objection that as soon as some of the plating wears off, exposing the other metal underneath, electrolytic corrosion sets in, and disintegration takes place rapidly.

Alloys

Of the numerous known alloys, Monel metal has been most extensively used although it is less satisfactory than certain types of stainless steel such as Allegheny metal. Mond metal as well as plain nickel and Corronil metals give similar results to Monel metal. Monel metal is attacked and coated with silver when stored in used fixing solutions.

Allegheny metal is quite resistant to both developing and fixing solutions, and has the least tendency of the commercial alloys to accumulate a deposit of silver in a used fixing bath. Also, very little corrosion occurs in a fixing bath if the alloy is completely immersed but if partially exposed to the air, corrosion pits form somewhat readily around the air line. However, it is the most satisfactory commercially available alloy.

Alloys often are more resistant to the action of certain acids and alkalis than the metals of which they are composed; as for example, Duralumin, whose tensile strength and resistance to acids is far above that of aluminum. Some samples of this alloy looked quite promising for use with photographic solutions while others were not satisfactory and for this reason the material cannot be unqualifiedly recommended.

Coated Metals

Enameled Steel

Enameled steel is extensively used for small tanks and has proven fairly satisfactory. When the undercoating of steel is laid bare by the chipping away of the relatively brittle vitreous enamel, it corrodes very rapidly, and the vessel is rendered useless. Smooth, hard enamel coatings are resistant to weak acids but with developers and alkaline solutions, the surface becomes etched, making it difficult to clean. Dye solutions permanently discolor such roughened surfaces of enamel.

Lacquered Metals

A satisfactory photographic lacquer consists of asphalt paint or a mixture of asphalt paint with rubber cement, the latter serving to overcome the slight brittleness of the asphalt coating. Baked japan is very satisfactory, but none of these materials will resist developing solutions containing a high percentage of alkali. Freshly applied asphalt paint will often produce a scum on the developer surface.

Non-Metallic Materials

Several satisfactory materials for use in handling photographic solutions on a large scale are to be found in the non-metallic group.

Glass

Glass apparatus well annealed, free from ribs, and with the corners rounded off, is quite satisfactory and is one of the most resistant materials available. For the storage of strong alkalis, special resistant glass should be used. Owing to its fragility, however, glass is not suitable for large tanks.

Impregnated Fibrous Materials.

Tanks prepared with fibrous materials impregnated with varnish or lacquer develop cracks with use, thus permitting access of the solutions to the under layers. Such tanks are entirely unsatisfactory for use with solutions containing strong alkalies, or with fixing baths, because these solutions disintegrate the fibrous materials through crystallization as explained later under "Porcelain and Glazed Earthenware."

Containers made from most laminated phenolic condensation products can be used with photographic solutions, with the exception of strong oxidizing solutions. Some samples of these materials have been found to swell and warp out of shape when used with strongly alkaline solutions.

Wood

Wood is fairly satisfactory for developing, fixing, and washing purposes, and is cheaper than any other available material. It has the disadvantage that, unless strongly braced, tanks have a tendency to warp out of shape. In many localities fungus growths accumulate on the outside of the washing tanks which must be removed frequently, while the inside of wash tanks often become coated with a layer of slime which necessitates frequent cleaning. Wooden containers also become permanently discolored if they are used for dye solutions. The most satisfactory varieties of wood for the construction of tanks are cypress, spruce, redwood, maple, and teak.

Paraffined Wood

Although certain woods such as cypress and teak are frequently used for the construction of containers for photographic solutions, paraffin impregnated wood is much more satisfactory. It also possesses the additional advantage that it does not tend to accumulate slimy layers as rapidly as unwaxed wood. The chief disadvantage of paraffined wood is that it is too heavy for the construction of large equipment which is to be handled manually. Methods of impregnating wood with paraffin have been investigated by Eberlin and Burgess,* who found that the best results were obtained with cypress and spruce by soaking in water for twelve hours, and then immersing in molten paraffin wax for two hours at around 257°F. (125°C.).

The soaking serves to swell the wood and in the hot paraffin bath the water in the pores is replaced by paraffin. The wood should be wiped thoroughly with a cloth on removing from the paraffin bath so as to remove the excess wax. Water-tight joints with paraffined

* "Impregnating Wood with Paraffin," L. W. Eberlin and A. M. Burgess, *Ind. Eng. Chem.* 19, (1927) 87, Revised 1928.

wood are best made by grooving the pieces of wood to be joined together, as for a T-joint, and inserting tightly a small piece of unparaffined wood in the groove. When placed in water the untreated strip swells and completely caulks the seam.

Porcelain and Glazed Earthenware

Porcelain, glazed biscuit ware, and tile material are usually unsatisfactory because the glaze invariably cracks, causing minute fissures into which the solution penetrates and crystallizes. The crystals then grow and cause the biscuit ware to disintegrate, incidentally causing the glaze to chip. Tanks of high grade, dark brown earthenware, glazed on both sides are especially recommended for storing ordinary developing and hypo solutions, but should not be used with strong alkalies.

Rubber, Rubber Composition, Nitrocellulose and Asphaltum Materials

Pure hard rubber will withstand practically all photographic solutions at normal temperatures. Some so-called hard rubber tanks are made from a mixture of asphalt or rubber composition with an excess of mineral filler. Such tanks are somewhat brittle, warp under heat, and when used as containers for solutions disintegrate in the same manner as porous earthenware. Smooth surfaces reduce the tendency to etching since less strain is exerted on the walls during the crystallization process.

Rubber sheeting and rubberized cloth are often used for coating the inside of wooden trays and troughs, and are very satisfactory. Cheap rubber sheeting or tubing often contains an excess of free sulfur which reacts with photographic developers and causes chemical fog.* Pure gum rubber materials are quite satisfactory.

A tarry material called "Oxygenated Asphalt" used for sealing storage batteries and supplied by the Standard Oil Company, has been found to be a satisfactory protective coating for use with all kinds of photographic solutions. This material is applied, while hot, as a thick coating over the metal or wood and if a smooth surface is desired the coating can be smoothed out by the use of a blowtorch. Nitrocellulose lacquer (E. K. Lacquer No. 5119) is useful for coating wooden articles such as racks for handling motion picture film, although several coatings are usually necessary, either by brushing, spraying, or dipping. Small apparatus constructed of nitrocellulose sheeting is satisfactory for use with almost every type of aqueous solution.** Wooden tanks lined with this material have also proved satisfactory.

Slate and Alberene Stone

These materials are very suitable for constructing large tanks for containing developing solutions. For fixing solutions, Alberene Stone (a gray, finely crystalline variety of soapstone) is quite satisfactory,

* "Chemical Fog" by J. I. Crabtree, *Amer. Ann. Phot.* 33, (1919) 20.

** "Plastic Cellulose in Scientific Research," K. Hickman and D. E. Hyndman, *J. Frank Inst.* 207 (1929) 231.

but slate is not recommended as it often splits along planes of cleavage as a result of crystallization. Some varieties of soapstone are not resistant to fixing baths, and tend to disintegrate where the sodium thiosulfate crystallizes out.

A satisfactory cement for joining large pieces of soapstone, as in constructing a tank, can be prepared from 1 part whiting, 2 parts litharge, thoroughly mixed and made into a putty with boiled linseed oil. A mixture of litharge and glycerine is recommended for cementing small fittings into the tanks.

Practical Suggestions

Materials suitable for constructing various types of photographic apparatus are as follows.

Small Apparatus

Allegheny metal is one of the most satisfactory materials known. Nickel, Monel metal, Mond, and Corronil metal are suitable for use in developing solutions.

Small Tanks

Since these containers are generally used for a variety of purposes, they should be resistant to most photographic solutions. Suitable materials are glass, enameled steel, hard rubber, teak wood or spruce impregnated with paraffin wax, wood or metal coated with "Oxygenated Asphalt," and well-glazed porcelain or stone ware. Allegheny metal, Monel, Mond, or Corronil Metals and Nickel with pressed seams or joints soldered on the outside are satisfactory for washing or developing and for fixing purposes when the tanks are to be used intermittently.

Deep Tanks

Alberene stone, well-glazed stoneware and wood (cypress) are suitable for developing and fixing baths. Lead-lined wooden tanks are fairly satisfactory for developing solutions provided the joints are lead burned and not soldered. Plain wooden tanks are satisfactory but they tend to accumulate slime. Tanks of paraffined wood can be used if the wood is properly joined together with strips of untreated wood as explained above. Tanks of portland cement have been found satisfactory for developers of low alkali content. Metal or wooden tanks coated with "Oxygenated Asphalt" are excellent providing the base material is not exposed.

Tubes, Sprockets and Idlers for Motion Picture Developing Machines

Hard rubber, chemical lead, Allegheny metal and Pyrex glass have been found satisfactory for developing tubes. Lead gathers a deposit of silver from the fixing bath, and in time this tends to obstruct the tube, but this deposit can be removed by scraping. Brass or copper tubing should not be used since both materials affect developers and are corroded by fixing baths. Idlers and sprockets should preferably be made of hard rubber or Allegheny metal according to the purpose for which they are intended. Metal tubing should not be soldered with solders containing tin.

Troughs for Reel Development

Glazed stoneware and wooden troughs lined with sheet rubber or rubberized cloth are satisfactory for practically all ordinary processing solutions. Lead, Mond, Nickel, Allegheny Metal, Monel, and Corronil metals are satisfactory for use with developing solutions but they are slowly attacked by fixing solutions. For acid oxidizing solutions or strong alkalies, glazed stoneware troughs are recommended but the troughs should be emptied after use. Metal troughs may be used in an emergency if the interior of the trough is lined with pure gum rubber sheeting or paraffined cloth. This latter lining is applied by coating the interior of the trough with cloth and sticking it to the metal with Cumar Resin (medium hard grade). The cloth is then brushed over with molten hard paraffin wax and the surface finally smoothed off with a hot iron. Metal troughs may also be coated with "Oxygenated Asphalt" but great care should be taken to insure that metal is covered completely and that the coating is free from bubbles. Japanned metal ware is only satisfactory for intermittent use.

Piping, Pumps, Faucets, etc.

For transporting developing solutions, hard rubber, iron (not galvanized), Duriron, and Allegheny metal piping and pumps are satisfactory and should be used in connection with faucets of similar materials. For transporting fixing solutions, hard rubber piping, valves and pumps are recommended. Tinned or tinlined, copper, or brass faucets or piping should be avoided for use with developers or fixing solutions. For conveying distilled water, however, pipe lines and fitting of block tin soldered with pure tin solder are satisfactory. Lead piping joints should be "wiped" or lead-burned, and not soldered. If silver-plated apparatus is used, the plating should be free from pinholes or scratches.

A suitable packing for pumps consists of asbestos rope twisted with the aid of a little hard grease.

Lead and hard rubber piping needs supporting while hard rubber must be protected from blows or excessive pressure.

The following table summarizes the above recommendations.

Construction Materials for Processing Apparatus

Solution	*Storage Tanks*	*Pipe Lines*	*Racks*	*Sprockets and Idlers*	*Coils*
Developer	Wood Iron Asphalt coated wood Lead lined wood Glazed earthenware	Black iron (not galvanized) Soft rubber	Allegheny metal Nickel Monel metal	Allegheny metal Monel metal	Nickel Monel metal Lead
Hypo not containing silver	Wood Lead Asphalt coated wood Glazed earthenware crocks	Hard rubber Soft rubber Lead	Allegheny metal Monel metal	Allegheny metal Monel metal	Allegheny metal Lead
Hypo containing silver	Wood Asphalt coated wood	Hard rubber Soft rubber	Allegheny metal Monel metal	Allegheny metal Monel metal	Allegheny metal
Water	Wood Iron	Galvanized iron Soft rubber	Allegheny metal Monel metal	Allegheny metal Monel metal	

Precautions to be Taken when Selecting Construction Materials.

1. Do not permit tin, copper, or alloys containing these metals to come in contact with developing solutions, especially concentrated developers, because more or less of the tin or copper will dissolve and cause either serious chemical fog or rapid oxidation of the developer. Do not use galvanized iron vessels to mix developing solutions containing sodium bisulfite because sodium hydrosulfite will be formed, which is a bad fogging agent. Likewise, the zinc in the inner coating of galvanized piping will cause developer fog.

Contact of two or more different metals or alloys exposed to a developer will hasten the rate of corrosion of the metals and thus increase the amount of fog obtained. Soldered joints are particularly to be avoided with developers, but if such joints are unavoidable, a low-tin solder or one free from tin should be used, and the joints so made that a minimum of solder is exposed to the solution.

2. For fixing, toning, and acid oxidizing solutions, avoid metals whenever possible.

3. When choosing metal for the construction of apparatus, a single metal should be used whenever possible, and it should be either electro-welded or soldered from the outside to avoid electrolyic corrosion. Lead containers should be joined together by lead burning.

4. Apparatus constructed of aluminum, zinc, or galvanized iron should not be used with either developers or fixing baths since these metals react with such solutions with the formation of precipitates which leave a deposit on the film and often stain the gelatin.

5. Plated metals should be avoided whenever possible and only single metals or alloys used in preference, since electrolytic corrosion sets in as soon as a little of the plating wears off.

6. For fixing baths or strong saline solutions, avoid porous materials such as incompletely glazed earthenware, impregnated fibrous materials, or rubber compositions, because crystallization of the salts within the pores of the materials causes disintegration.

7. Tanks coated with lacquer or baked japan are not resistant to strongly alkaline developers or fixing baths of high acid concentration.

8. Avoid the use of cheap rubber tubing or other materials containing free sulfur or metallic sulfides in connection with developing solutions, because the alkali in the developer attacks these, forming alkaline sulfides which cause chemical fog.

Desert Study C. Curtis Fetters, A. S. C

EFFECT OF THE WATER SUPPLY IN PROCESSING MOTION PICTURE FILM

*J. I. Crabtree and G. E. Matthews**

WATER is the most widely used chemical in the processing of motion picture film and it is important therefore to know to what extent the impurities present in it may be harmful to the various operations and how these impurities may be removed.

Impurities in Water

Excluding distilled water, rain water, and water from clean melted ice or snow, impurities may be present as follows:

1. Dissolved salts such as bicarbonates, chlorides, and sulfates of calcium, magnesium, sodium and potassium.
2. Suspended matter which may consist of:
   (a) Mineral matter such as mud, iron rust, or free sulfur.
   (b) Vegetable matter such as decayed vegetation.
   (c) Animal matter such as biological growths and bacteria.
   The suspended particles may be of colloidal dimensions when they are difficult to remove by filtration.
3. Dissolved extracts usually colored yellow or brown from decayed vegetable matter and the bark of trees.
4. Dissolved gases such as air, carbon dioxide, sulfur dioxide, and hydrogen sulfide.

Effect of Impurities on Processing

Development

1. If a developing solution is prepared with water containing calcium salts, a white precipitate consisting largely of calcium sulfite, but with some calcium carbonate, is apt to form on mixing.

In some cases a precipitate does not form immediately but a sludge[1] consisting of fine needle-shaped crystals of calcium sulfite separates out on standing (Fig. 1). Magnesium salts, unless present in excess, are not precipitated. Such a sludge or precipitate will settle out on the emulsion side of film, plates, and papers and cause spots.[2] The white precipitate or sludge is harmless, however, if allowed to settle and only the clear supernatant liquid drawn off for use.

The developer, of course, is robbed of sulfite and carbonate to the extent of the quantity required to form the sludge or precipitate, but except in the case of developers of low alkalinity, this effect is negligible. Experiments have shown that the quantity of calcium or magnesium salts occurring in average natural waters in the United States is insufficient to produce any appreciable effect on the developing power of developers containing 0.3% sodium carbonate by virtue of a lowering of the carbonate content.[3]

**Kodak Research Laboratories.*

However, in the case of developers containing borax, which are very sensitive to slight changes in alkalinity, the presence of an appreciable quantity of calcium salts would be sufficient to lower the alkali content and due allowance for this should be made.

Salts liable to be present other than the above are chlorides and bromides of the alkali metals which exert a restraining action. Sodium carbonate which is present in certain alkaline waters tends to speed

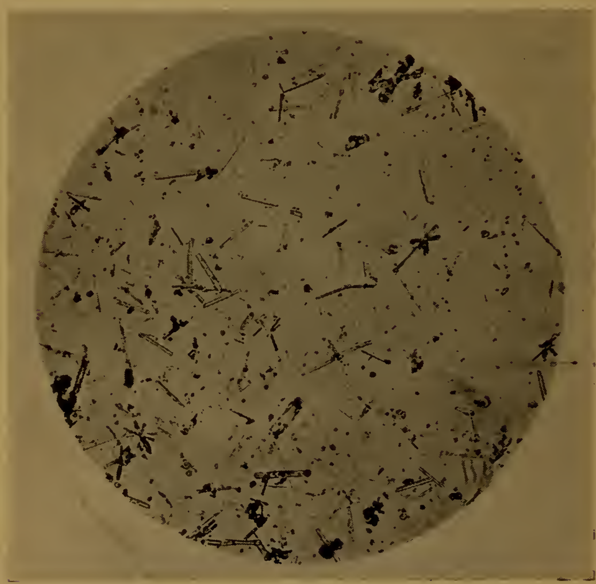

Fig. 1
Photomicrograph of developer sludge (calcium sulfite) caused by presence of calcium salts in water supply.

up the action of a developer weak in alkali, although with the average developer the concentration of the alkali in the water used for mixing is insufficient to exert any appreciable effect.

Developers mixed with water containing sodium or potassium sulfides will give bad chemical fog even if the sulfides are present in very small quantities.

It is customary to add copper sulfate to certain water supplies at periodic intervals in order to kill vegetable and biological growths. While the presence of 1 part in 10,000 of the copper salt in a developer will cause aerial fog,[4] the concentration of the copper salt in the water supply usually is much lower than this.

2. A. Dirt and iron rust suspended in the developer solution often produce spots and stains. In the case of a pyro developer the iron is apt to combine with the pyro forming an inky compound which imparts a bluish red color to the solution although photographically it is harmless.

Particles of finely divided sulfur which give the characteristic opalescence to sulfur waters will cause fog owing to the formation of sodium sulfide by interaction with the carbonate present in the developing solution. If the water is boiled, the colloidal sulfur usually coagulates, when it may be separated by settling or filtration.

B. Vegetable matter is usually precipitated by the salts present in the developer.

C. Animal matter is usually precipitated on mixing the developer, but frequently biological growths and bacteria thrive in a developer and form a slime or scum on the walls of the tank. Some types of these growths act on the sulfite in the developer, changing it to sodium sulfide which fogs the emulsion very badly. The sulfide is removed by developing some waste film in the solution or by adding a small quantity of lead acetate to the developer in the proportion, 25 grains per gallon (0.4 gram per liter).[5] Tanks which show a tendency to accumulate slime should be scrubbed out with hot water at regular intervals and then treated with a dilute sodium hypochlorite solution.[3] Suspended mineral, vegetable, or animal matter in general has usually no harmful effect on a developer, providing the mixed developing solution is allowed to stand and only the clear supernatant liquid drawn off for use. Mixing the developer with the aid of warm water tends to hasten the rate of settling of the suspended matter.

3. Extracts from decayed vegetable matter or the bark of trees usually discolor developing solutions but are often precipitated if the developer is prepared with warm water and allowed to stand. The staining effect of such extracts with motion picture film is usually negligible.

4. Water dissolves about 2% of air at 70° F. and when a developing agent like hydroquinone is dissolved without the addition of sulfite the oxygen present in the water combines with the developing agent, forming an oxidation product which is apt to stain the gelatin and fog the emulsion. Air in water occasionally collects on the film in the form of little bubbles or airbells which prevent development giving rise to characteristic markings.[6] When developing at high temperatures (above 80° F.) dissolved air often causes blisters.[7]

Mineral waters containing carbon dioxide rarely give much trouble providing the water is boiled first in order to drive off the gas. If carbon dioxide is present in excessive amounts in a developer, it acts in the same way as dissolved air, producing bubbles and airbells on the film, causing blisters.

Hydrogen sulfide gas will cause bad chemical fog in a developer but may be removed by boiling the water or by precipitation with lead acetate before mixing.[4, 5]

Fixation. Calcium and magnesium sulfites are soluble in acetic acid and therefore are not precipitated in fixing baths. Other dissolved salts such as bicarbonates, chlorides, and sulfates are harmless. Suspended matter such as dirt, iron rust, and certain types of vegetable and animal matter usually will coagulate and settle out on allowing the fixing bath to stand.

Although most suspended substances have practically no effect on the photographic properties of fixing baths, the particles may settle on the film, locally retarding fixation, and produce spots and stains.[2]

Extracts from vegetable matter or dissolved gases do not affect the photographic properties of a fixing bath, but are liable to cause stains and blisters, and locally retard fixation.

Washing. Dissolved salts often cause trouble by crystallizing on the film after drying, and although not always visible as crystals to the eye, they detract from its transparency (Fig. 2). Water which is free of dissolved salts also will cause markings on film providing it is allowed to remain in droplets on either side of the film during drying.[8] It is important therefore to remove thoroughly all excess water from the film before drying. This can be accomplished, (a) by draining thoroughly before applying a current of air; (b) by swabbing with wet absorbent cotton or chamois; and (c) by means of a pneumatic squeegee.[9]

Suspended mineral, vegetable, and animal matter usually produces a scum on film unless the gelatin surface is wiped carefully previous to drying. If the water used for washing is run into a large settling tank or is filtered before using for washing purposes, most of the suspended matter will be removed.

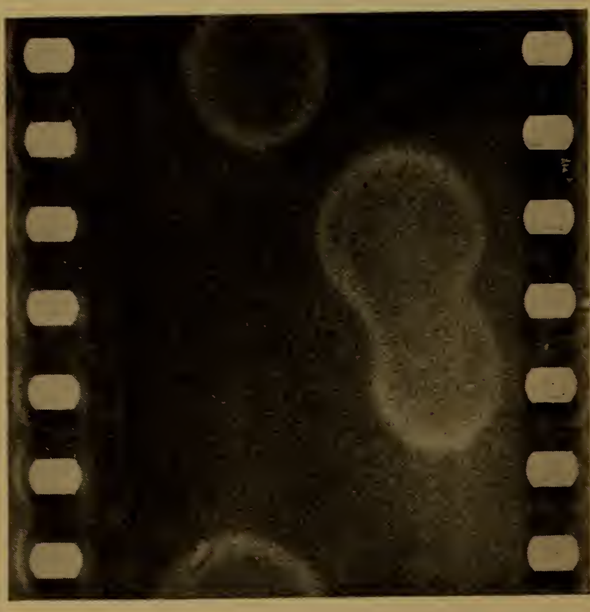

Fig. 2
Appearance of scum on motion picture film after evaporation of drops of water containing dissolved salts.

Dissolved extracts produce stains which are very difficult to remove. Also, if the wash water is warm, dissolved gases will sometimes produce blisters, especially if the film is not hardened sufficiently in the fixing bath.[3]

So far as is known, any small traces of impurities left in the gelatin coating of motion picture negative or positive film after drying, by virtue of the presence of these impurities in the wash water, are not liable to seriously impair the keeping properties of the films over a period of four or five years. However, films which are to be kept for long periods of time should be finally washed in distilled water.

The Preparation of Dye Solutions

Many dyes are precipitated out of solution by calcium or magnesium salts and alum. The precipitation is not always immediate and may occur only after standing for a few days. The properties of dyes with respect to their rate of penetration into gelatin or the rate at which they are mordanted are affected considerably by the presence of metallic ions, or acids, or bases, so that in color photography or when using desensitizers impurities in the water are apt to produce anomalous results. Distilled water should be used whenever possible for preparing solutions of dyes.

Method of Purification of Water

Distillation. Distilled water should be used whenever possible for mixing solutions.

Boiling. Unless the water contains an excessive quantity of dissolved salts, it is sufficient usually to boil the water and allow it to settle. The supernatant portion then may be syphoned off or the solution filtered through fine muslin. Most colloidal vegetable and animal matter, comprising slimes and scums, coagulates on boiling and certain lime salts are changed to an insoluble condition and settle out. Dissolved extracts are not removed but dissolved gases are driven off by boiling.

Filtration. Various types of water filters are available commercially, but these do not remove dissolved salts or colloidal matter unless the water has been treated previously with a coagulant.

Chemical Treatment. The following methods of chemical purification may be adopted:

1. Potassium alum may be added in the proportion of 1 gram to 4 liters of water. This coagulates the slime which carries down any suspended particles and clears the solution rapidly. Dissolved salts are not removed by this method. The small percentage of alum introduced into the water has no harmful effect on the solution when subsequently used for mixing developers and fixing baths.
2. A solution of sodium oxalate may be added until no further precipitate forms. This method removes the calcium and magnesium salts and coagulates the slime though other dissolved salts are left in solution. Solutions of sodium phosphate and of sodium sulfite also may be used to precipitate calcium and magnesium.
3. Most of the commercial methods of water softening may be employed although such methods do not remove sodium and potassium salts. One of the most satisfactory consists in passing the water through a tank containing sodium aluminum silicate which is zeolite, and possesses the power of exchanging its sodium for the calcium and magnesium present in the water.

Sodium aluminum silicate + calcium sulfate = sodium sulfate + calcium aluminum silicate.

(Zeolite)

When the zeolite thus loaded with calcium and magnesium is washed in a strong solution of common salt (about 12%) it exchanges its calcium and magnesium again for sodium and is thus regenerated, whereupon the chemical may then be used for further softening.

Calcium aluminum silicate + sodium chloride = sodium aluminum silicate + calcium chloride.

(Zeolite)

The Use of Sea Water

Sea water contains a relatively large proportion of soluble salts (about 3½%) and should not be used for mixing photographic solutions except in extreme emergencies when no other water is available. This is because the dissolved salts such as chlorides, and iodides may retard the action of the photographic solution. When the supply of fresh water available is very small, sea water may be used for washing motion picture film, providing a last washing or soaking previous to drying is given in distilled or fresh water.[10] The film should be given a thorough washing later when plenty of fresh water is available.

A chemical analysis of the water supply usually reveals very little concerning its photographic usefulness. It may be of some assistance in indicating the quantity of lime, oxalate, etc., to be added to remove dissolved calcium salts or to coagulate slimes. The quantity of total solids indicates if trouble from drying marks may be anticipated, while the presence of iron, hydrogen sulfide or metallic sulfides should be regarded with suspicion. The only useful test is to prepare a developer with the sample and actually try it out compared with the same developer prepared with distilled water.

Also, a large drop of water should be allowed to dry on the film and the amount of residual scum observed. This will indicate the extent of the trouble to be expected if the water is not removed thoroughly before drying.

Practical Recommendations

If developing solutions are mixed with warm water (about 125° F.) and allowed to stand over night, any precipitate or suspended matter will settle out and the clear supernatant liquid may be drawn off for use. The presence of calcium and other salts in the water supply is sometimes beneficial insofar as they tend to retard the swelling of the gelatin coating of the film during washing. This is of particular advantage in hot weather.

The only impurities liable to cause serious trouble with developers are hydrogen sulfide or soluble metallic sulfides. With such water about 25 grains of lead acetate per gallon of developer (0.4 gram per liter) should be added before mixing. This removes the sulfides as lead sulfide and any excess lead is precipitated in the developer and settles out on standing.

No trouble may be anticipated with fixing baths prepared with average samples of impure water providing the bath is clarified by settling before use.

When washing photographic materials little trouble may be anticipated with uncolored water if the following precautions are taken: (a) remove all suspended matter by filtering, either by means of commercial filters or by placing two or three layers of cloth over the water outlet; (b) remove thoroughly all excess moisture from the film before drying.

Water which even after filtering is colored brown is very apt to cause staining of the highlights. It is a difficult matter to remove economically the coloring matter from such waters and each case usually requires specific treatment.

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Interior Set

THE ART OF MOTION PICTURE MAKE-UP

*Max Factor**

AS I LOOK back on time and reminisce over my experience, which has been crowded with interesting contacts with celebrities of stage and screen, I recall the time when make-up was not the subtle art it is today. As a matter of fact, it was not until comparatively recent years that the science of make-up really gained recognition as an art. But, art it is, and one of the most important arts in the motion picture business.

Without make-up, properly applied, the players would appear as almost hideous individuals on the screen. With make-up artfully applied even a decidedly homely woman can be made to look beautiful, and close-ups become joys to the observer. However, there are not many people who can make themselves up without considerable instruction. The art of make-up, like other arts, is not something that comes naturally to all. As a matter of fact, I have given most of my life to the study of make-up, and am constantly learning new and fascinating tricks of the trade.

As there are no two complexions or faces exactly alike, each individual presents a different problem. In a word, make-up must start where Nature left off. The task is to fit the face for the part, and some parts are so unique that they challenge the skill of the make-up artist.

Yet it is fair to say that type-creating make-up and its application has been developed to a high degree of achievement. Indeed, some of the effects gained with make-up have been so wonderfully successful that many have come to believe that with an average outfit of make-up materials a thousand possibilities await the studious mind and the skillful hand.

To the beginner, let me say this: The art of make-up calls for great patience and earnestness, plus practice. With the will to master the art, and with the proper patience, one can become proficient in make-up; but it requires earnest work. In this article I shall attempt to give as practical and complete an outline of the procedure in making up for the screen as possible. I shall try to give as simple and comprehensive a method for beginners, amateurs and professionals as can be done.

This outline is the result of twenty years of study and experiment in the science and art of make-up, and before I give it to you I wish to express my appreciation to the *Motion Picture Make-Up Artists Association*, the *American Society of Cinematographers* and the *Academy of Motion Picture Arts and Sciences* for their valuable cooperation in bringing the art of make-up to its present high stage of development.

**Internationally famous authority on make-up and head of the Max Factor Make-Up Studios, Hollywood.*

Today what we call Panchromatic Make-Up is the rule, being used by every studio in America and the principal studios throughout the world. And the development of Panchromatic Make-Up we consider one of the most important achievements in the art. This was brought about because of the introduction of Panchromatic film, a film sensitive to all colors, recording them in their true, harmonious relations, and eliminating finally those sharp, hard contrasts so common with the use of the old-time orthochromatic film.

When this film was introduced our organization, together with the organizations mentioned above, went into the matter of make-up for the new film at Warner Brothers' Studio in Hollywood. And there we worked out the Panchromatic Make-Up which gives the screen performer a standard range of complexion tones that balances, and which can withstand the color absorption properties of every modern lighting device. Further, this new make-up enabled the Cinematographer to attain more natural and desirable results. In motion picture making, make-up is an exacting art. The keen eye of the camera sees every detail and imperfection, and the projector magnifies them, so the greatest care must be exercised.

At this point it might be well to mention some of the important uses of make-up with respect both to performer and Cinematographer.

1. Disfigured faces and objectionable blemishes, since they are magnified by the camera, may be rendered invisible, or at least subdued, by the correct uses of make-up.

2. The natural contrasts which give tone and color to a complexion are lost in the photographic process. The adjustment is easily made by the use of color in make-up.

3. Faces that have become tanned and sunburned can maintain their true characterizations throughout the making of a picture with the use of make-up.

4. During the making of a picture the strain of hard work and long hours may show its signs. Make-up subdues these evidences of fatigue and permits the original characterization to go on unchanged.

5. Retouching of photographs is a highly skilled art. It is even difficult in still photography, resulting too often in the subject wearing an unnatural or false expression. For motion picture photography retouching is physically impossible. Artistically done, make-up is the most practical way to correct and adjust facial deficiencies.

6. Since make-up has contributed to the perfection of cinematography it has been applied with equal results to portrait photography.

Directions for the Application of Make-Up

1. *Preparing the Face*—The face must be thoroughly clean before make-up is applied. The best way is to wash the face with soap and water. Men should be smoothly shaven. .

2. *Base for Grease Paint*—It is often necessary to use cold cream before applying grease paint. In my laboratory, however, we have developed a grease paint which eliminates this need.

3. *Grease Paint Application*—Squeeze about one-quarter of an inch of grease paint from the tube into the palm of the hand. Then with the tips of the fingers of the other hand apply the grease paint in "dibs and dabs," covering the face with little dots of grease paint until it acquires the appearance of a freckled face. Grease paint must be applied sparingly, too much will spoil your make-up.

4. *Spreading Grease Paint*—Now remove the grease paint from the hands and dip them into cool water, then with the finger tips moistened with water spread the grease paint over the face, blending it smoothly, evenly and thinly into the skin. The movement of the fingers should be from the center of the face outward. Keep dipping finger tips into water as it is essential to blend the grease paint in order to have a smooth and thin application.

5. *Shadowing the Eyelids*—Apply a thin film of lining color to the eyelids with the finger tips, using a light outward motion, blending it carefully upward and outward toward the eyebrows and the outer edge of the lids. No decided line should be visible. Only in special cases should a shadow be used on the lower lids.

6. *Penciling Eyes*—Line the upper and lower lids by drawing a fine line with the dermatograph pencil where the eyelashes meet the eyelids. Draw this line outward and extend just a trifle, the smallest fraction of an inch.

7. *Moist Rouge*—Apply the rouge to the lips, being sure to give an application to the inside of the lips, so that when the mouth is open, smiling or talking, the line of the rouge will not be seen.

8. *Important Rule*—It is important to follow the application of the cosmetics in exactly the rotation given. All these cosmetics have an oily base and it is essential that all make-up having an oily consistency should be applied before powder or dry make-up is used.

9. *Applying Face Powder*—Then apply the powder. This must be done with a patting motion. Pat the powder on until it is absorbed by the grease paint. Apply the powder over the lip rouge and eye lining profusely. If there are wrinkles around the eyes, pat over them again, drawing the wrinkles apart.

10. *Removing Surplus Powder*—To give your complexion a smooth and velvet finish it is of vital importance to remove your surplus powder. Brush the entire make-up lightly with a special brush and carefully remove every particle of extra powder.

11. *Lip Effect*—After removing the powder from the lips, moisten them with your tongue. This will result in a fine, natural color and the rouge will stay on without retouching.

12. *Make-Up the Eyebrows.*—Either a dermatograph pencil or masque may be used. If a pencil is used, draw short, little hair lines, following the natural shape of the eyebrows and accentuating the shape desired. If masque is used, wet the brush and rub on the cake of masque. Now, with the brush apply the masque lightly to the eyebrow.

13. *Make-Up for Eyelashes*—Men as a rule do not make-up the lashes. Women may use either masque or cosmetic. You can accentuate the lashes effectively with masque, but if you want to give the appearance of beaded eyelashes cosmetic should be used. Place the cosmetic in a small container and hold over a flame until melted. Dip paper liner or orangewood stick into melted cosmetic and apply to the lashes. For beading apply cosmetic to the tips of lashes repeatedly until they acquire the desired beaded appearance. The bead should hold about two or three lashes.

14. *Completing Face Make-Up*—Smooth out the make-up and rebrush it over very carefully with powder brush.

15. *Liquid Make-Up*—Women should make-up the shoulders, arms and other exposed parts of the body to harmonize with the face make-up. For this purpose liquid make-up is used. Start the application at the neck where the face make-up stops. Apply make-up to the neck, arms and hands. Apply with stroking motion and rub one way only until dry. This make-up is easily removed with soap and water.

16. *Removing Make-Up*—Cold cream will dissolve grease paint make-up. Massage the face well until all the make-up is completely dissolved. Then wipe the face thoroughly. It is advisable to wash the face immediately with warm water and plenty of soap, and then rinse in cold water.

17. *Artificial Eyelashes*—The eyelash adds much beauty and charm to the expression of the face and is a useful and an ornamental feature. To the women who has been deprived of a natural growth of luxurious hair on the lashes, this may come as an aid of great value. The artificial lash, very simply applied, defies detection, and can be worn on stage, screen or on the street. The lash should be cut to fit the lid from each corner of the eye. Spread a film of spirit gum on the foundation of the lash. Allow to dry for a minute, then press the lash firmly against the eyelid, directly above your own lashes.

Chart Suggesting Correct Shades of Make-Up

The following chart will give you approximately the correct shades for various types. The color scheme of "in-between" types may vary, *i. e.*, a blonde type may have hazel or grey eyes; a brunette may have blue or grey eyes. But ordinarily, a color of both hair and eyes distinguishes the blonde from the brunette as follows:

Blondes: Blonde hair, blue eyes and fair skin.

Brunettes: Dark hair, dark eyes, medium skin.

The colorings of Panchromatic make-up are neutral tones of tan and warm brown. When it is completely applied the effect is a monotone complexion, which is the correct color for the best photographic results, with any type of film stock used.

	Women		*Men*	
	Blonde	*Brunette*	*Blonde*	*Brunette*
Panchromatic Grease Paint	24	24	26	26
Panchromatic Face Powder	24	25	26	27
Panchromatic Lining Color	21	22	22	22
Panchromatic Masque	Brown	Brown	Brown	Brown
Panchromatic Dermatograph Pencil	Brown	Brown	Brown	Brown
Panchromatic Moist Rouge	8	9	7	7

	Elderly Types		*Children*	
	Women	*Men*	*Female*	*Male*
Panchromatic Grease Paint	No. 23	25	22	24
Panchromatic Face Powder	23	26	22	24
Panchromatic Lining Rouge	21	21	21	21
Panchromatic Moist Rouge	8	7	8	7

Panchromatic Masque	Brown	Brown	Brown	Brown
Panchromatic Dermatograph Pencil	Brown	Brown	Brown	Brown

(For extreme types the number may vary to suit the conditions).

Individual Panchromatic Make-up items are known by numbers as follows:

Panchromatic Grease Paint	Nos. 21, 22, 23, 24, 25, 26, 27, 28, 29
Panchromatic Powder	Nos. 21, 22, 23, 24, 25, 26, 27, 28, 29
Panchromatic Lining	Nos. 21, 22
Panchromatic Lip Rouge	Nos. 7, 8, 9
Panchromatic Dermatograph Pencil	Brown

The lowest numbers represent the light shades, and as the numbers become higher the shades are correspondingly darker.

Dry Rouge is eliminated in make-up for black and white motion picture photography.

Basic Principles of Character Make-Up

Let us start by defining the word "character" as it applies to the acting profession. It is the representation of a particular personality, an impersonation, if you will, as interpreted by an actor. And he is a great actor only insofar as he creates in his audience that necessary "suspension of disbelief." He must look like an actor. He must look his part. And he does this by making a careful study of every phase of it. If the character he is to play is not vividly clear to him he will seek out authentic sources,—examine pictures, read descriptive material, and he may observe his model in real life . . . in the mines, the Ghetto, or wherever his problem takes him.

It is an erroneous notion that "any old way" will do in making up. The art of make-up is full of details, and to be slip-shod about any of them may entirely affect the success of a performance. Good make-up creates an illusion, but there is no illusion about a poor make-up. No matter how far back you are from the camera, or how unimportant your part, it is not good business to try to fool your audience with poor make-up. True, the work calls for studied detail, but on the motion picture set there is nothing trivial about details.

High-lighting nose, cheeks and chin

Face properly shadowed

High Lights and Shadows

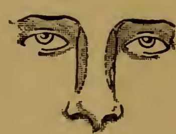
In make-up this is an art that employs only light and shade, an arrangement or treatment of light and dark parts, to produce a harmonious and effective characterization. High lights are contrasting shades, skillfully blended with the foundation color of the complexion. Every dark line that is drawn on the face should be high lighted with a much lighter shade, and the edges must be properly blended with the complexion.

High lights are used to give prominence to the nose, cheeks, chin and wrinkles whenever it becomes necessary, in creating a particular character. To high light these features; use a lighter shade of make-up than the ground tone that is being used on the rest of the face. For ordinary high lighting use a shade three or four times lighter than the base. For extreme high lighting, use white or yellow lining colors. To make shadows or low lights use colorings of a darker shade than the ground tones of the complexion. In straight make-up shadows can be used to offset features that are out of pleasing proportion. In special character make-up, shadows are employed to produce sunken features by blending them with high lights.

To sink or hollow the cheeks and temples use shadows of gray or brown, high lighted with contrasting white or yellow, and blending the whole into the ground color. In most cases, in making low lights, do not use black. Use grey, maroon or dark brown.

Showing the natural nose

The same one high-lighted for a character part



A wide nose, shadowed to improve proportions

The Nose

While there are significant differences in the proportions of the nose among different types of people, it might be helpful to know the general standard of proportions accepted by most sculptors and portrait painters, as follows:

1. The length of the nose must be equal to that of the forehead.

2. A front view of the nose should give the arch a little more width near the middle.

3. The point must be neither round nor fleshy. The lower contour, precisely outlined, neither narrow nor wide.

4. The flanks must be seen distinctly.

5. In the profile, the lower part of the nose should be only one-third its length.

6. The sides of the nose form a wall.

When these proportions are required the use of high lights and shadows will give the effect. To make the nose thinner and more prominent use a high light on the bridge of the nose of a much lighter shade than the ground color of the complexion, carefully blending the sides with gray shadow or red brown.

To tilt the nose upward use brown shadow in a triangular shape underneath between the nostrils.

The Eyes

In the eyes we can read many human emotions—sadness, hope, fear, defiance, anger, wistfulness, contemplation. Further, the characteristics of the eyes—the shape, color, setting, eyebrows—indicate types of personality. The eyes can be made to appear offensive or

Left: Normal eyes well shaded. Center: Enlarging the eyes by lining the lids. Right: Crow's feet and age lines.

unfriendly if they are set too near or far apart. The arrangement of the eyebrows should be in accordance with the desired effect.

Sunken eyes may give a threatening or sombre look, depending on how the sunken effect is treated with relation to the other features of the face. To make the eyes appear larger draw a line with the dermatograph pencil around the upper and lower lids. This line must be drawn a reasonable distance from the lash lines, allowing the skin to be visible. The effect is best achieved at the outer corner of the eyes.

The Mouth

The mouth may be called the most sympathetic part of the face. Its mobility makes it readily responsive to our innermost feelings; indeed, the mouth sometimes betrays our deepest thoughts. With the eye it makes up a language that is unmistakably communicated.

In making up the feminine lips the width and the cupid's bow should be in pleasing proportion to the other features. To achieve this, sometimes the natural lip lines may have to be concealed. This is done by applying lip rouge, forming the desired shape and size, then carefully spreading the ground color with a tinting brush to the edges of the new lip line. To hide line of demarcation or impression of such, pat the complete surface of the concealed line with the index finger.

Men, in applying lip rouge, must avoid the appearance of a cupid's bow. Strange to say, this is often overlooked. If one lip is more prominent than the other, use two shades. A dark shade to subdue the prominent lip and a bright shade to accentuate the other.

A jovial, good-natured expression is affected by tilting the ends of the mouth upward. A worried, haggard, painful expression is made by drooping the ends of the mouth.

Left to Right: Natural lip line. Same lips made smaller. Jovial mouth. Tragic mouth

The Chin

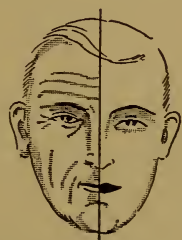
This feature offers the fewest problems. There are two characteristic types of chins—receding and protruding. The protruding chin may be pointed or rounded. To bring it into harmonious proportion with the other features, shadow with several shades darker than the ground tone, blending the edges into the complexion. On round, protruding chins, apply shadow to center, spreading over entire area; on pointed chin, apply mostly on tip of point. To build up the receding chin, high light the entire area of the chin by applying a much lighter shade than the ground tone of the make-up used.

High lights on nose and chin

Low lights on chin and cheeks

Wrinkles

Wrinkles are creases in the skin showing the effects of age or the emotional experiences. The professional method of applying wrinkles is the most practical one. After the ground color has been applied, you locate the natural position of the wrinkles by distorting the face, forcing the wrinkles into them. Then while you hold them fixed, mark them.



Youthful face wrinkled for age

On relaxing your face you have a pattern of the wrinkled expression you require. With a dark red or brown lining color (sometimes it is convenient to use a dermatograph pencil), you draw over the lines of your pattern to give them more striking effect. To achieve greater accent you must high light every wrinkle.

Colors suggested for high lights are: Lining colors, Yellow No. 11 and White, No. 12. Colors for shadows or low lights are: Lining colors, Dark Brown, No. 2, Light Brown, No. 3, Blue-grey, No. 6 and Maroon, No. 9. Black or Brown dermatograph pencils can be used conveniently.

Left: Crepe hair unravelled. Center: Combing out crepe hair. Right: Trimming ends evenly

Crepe Hair

A braided hair material prepared for making beards, mustaches and eyebrows can be purchased by the yard, and comes in many shades. For ordinary use, a yard will last practically a year.

False Beards

For the average beard, a natural effect can be obtained if the crepe hair is built directly on the face. Beards, sideburns and mustaches give the face a natural, mature expression. The art of manipulating crepe hair will prove to be a great advantage in portraying many character parts. The rules below, combined with practice, will give you a workable knowledge.

1. When unbraided, the crepe hair is very curly and kinky. It must be straightened before using. First, moisten thoroughly. Then, while damp, tie each end firmly with string. Draw the hair out while it is taut and straight, stretching between two objects until it is dry. It is suggested that the hair be prepared in this manner the night before it is to be used.

2. When the hair is straight and dry, the quantity to be used should be combed. This is done on a hair-worker's hackle, or it can be done with an ordinary comb. Two or three shades of hair can be used in the same beard. The hair can be stacked neatly within convenient reach to be applied.

3. A thin coating of spirit gum is applied to the face where the hair normally grows. The application of spirit gum is an important detail toward creating a natural looking hairline.

Left: Adhering trimmed ends to spirit gum. Center: Trimming beard to shape
Right: Finished beard

4. Laying the hair in the direction in which it naturally grows is the most important detail. It is a good idea to study a real bearded man and note in what direction the hair grows on different parts of the face. Under the chin the hair grows toward the front, and on the sides grows down. To imitate nature and to reproduce it as accurately as possible, every detail must be carefully observed.

5. Take a small amount of hair from the prepared stack and cut the top ends evenly to the general angle that your beard is going to take. The ends only are to adhere to the spirit gum. Start at the chin, placing your first layer of hair at the lowest point under the chin and work towards the front with each succeeding layer.

6. When all the necessary hair has been applied, press the hair to the face with a towel, holding it firmly a few seconds. Do this to every section so that you are sure the hair sticks. Holding the ends of the hair in place with your fingers, comb out the loose hair very gently.

7. Now the beard can be combed and brushed as a real beard. It is then trimmed into any style with all the realism of a barber's art. A pair of tweezers will come in handy to remove odd hairs that affect the smartness of the hair line.

Applying mustache

Unshaven effect

Mustache

To build a mustache, prepare the hair as described under the process for the beard. With your thumb and index finger remove sufficient amount of hair from your prepared stack. Trim ends on a bias. After coating your upper lip with spirit gum in the shape of the desired mustache, apply the hair, beginning at the outer corner of the lip and shingling up toward the center. When all the hair is applied, press a towel against your mustache so it adheres firmly to the face. Hold it in place with your fingers and with a comb remove loose hair. Then trim the mustache neatly with scissors. You can brush the mustache lightly with spirit gum, to set the hairs in place, and shape with mustache wax. This gives it a natural appearance.

Unshaven Effect

A grey-blue or red-brown lining color is the shade to be used for the effect of an unshaven face. The illusion-creating color is applied with a porous rubber sponge. Smear the sponge well with the color you intend using, then stipple it over the ground tone of your complexion; this is done before powder is applied. The effect of this illusion is created by stippling the lining colors in the normal area of the beard, creating a natural looking hair line. This effect can also be produced with crepe hair. Apply spirit gum over the entire area of the beard growth. Cut the crepe hair into small bits of short hair and place over the spirit gum, being sure to distribute it evenly.

Modelled character nose

Character chin

Nose Putty

A soft, plastic material, sometimes called Nose Paste, used for many other purposes than that which its name implies, is effective for nose work. For changing the contour of the nose or building up the nose into desired shape and for changing the chin it is excellent material.

Nose paste can effect a complete disguise in make-up by changing the entire expression. It is without a doubt the finest means to conceal your natural eyebrows. The nose paste forms a hairless base and is completely concealed by the ground color of your make-up. It is then powdered, making it possible to apply any type of eyebrow with a dermatograph pencil or crepe hair.

Note:—Before using nose putty it must be made pliable. This is done by taking sufficient of it and kneading between the fingers until it is very soft. Then it is ready to be used.

Left: Oriental. Center: Mephisto. Right: Svengali

The Eyebrows

The accompanying illustrations show only a few of the striking types that are characterized by the arrangement of the eyebrows, features that are especially notable in the Oriental, Svengali and Mephisto types.

In the Oriental eyes the brow is quite a distance from the upper lid and the eyes take on a decided almond shape. The shape is created with the dermatograph pencil, extending the line on the lower lid at the outer corner of the eye upward to be parallel with the new eye-

Angry

Haughty

brow. The line on the upper lid extends slightly down on the nose on the inner corner of the eye.

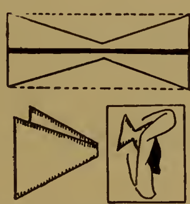
The Svengali eyebrows are decidedly pronounced. Heavy and close eyebrows are most always associated with brutal, fiendish types. Mephisto's pointed nose and chin by no means consummate the character. The eyebrows properly shaped complete his characteristic expression.

Scars

There are many types of scars. When it becomes necessary to make a scar, we should understand its construction and the art of creating a realistic effect. There are many methods, but we will describe in detail the simpler ones known to the profession.

1. Welts—The average scar appears as a welt and not as an indentation. It is caused by a blow, and is somewhat different from that caused by a knife wound. This type of scar can be created by the use of a nose putty. Apply the nose putty over the scar area, building up in the center and smoothing off the edges into the foundation make-up. The raised surface may be colored with a grey-blue lining color, No. 6, accentuating the bruised part of a welted scar. The line of a scar should be irregular and never straight.

2. Indentations—(Use of Collodion). Non-flexible collodion is used for making indentations—it gives a realistic effect. Apply it with a brush directly on the place where the scar is desired. Allow to dry, and if the recession is not deep enough, apply another film of collodion and allow to dry. Repeat until recession is as desired. Usually, three or four applications are sufficient. Collodion scars may be removed by dissolving with Acetone, or they may be peeled off.



Cauliflower ear device

An indentation scar may be effected by the use of nose putty. Spread it well over the spot where you wish the scar, raising up the center and smoothing the edges well into the complexion. Then, with a paper stump or any similar instrument, make a crease in the center and line it with dark Red color, No. 9 lining color. High light with No. 11 Yellow, or No. 12 White and blend the edges well together.

3. Old, Flat Surface Scars—In making an old scar, it is a matter of resembling the discolorations by the use of proper colors. Scars may be of any conceivable size or color. The dark parts of scars require a low light—a No. 9 lining color, Maroon. Highlight edges with a contrasting color, a No. 12 White or a No. 11 Yellow. The illusion is completed when the edges are carefully blended. Some

scars can be made to appear very natural by touching up here and there with a little Purple, No. 8, and Yellow, No. 11.

Cauliflower Ears

To create the natural effect of a cauliflower ear, take a piece of cardboard about half an inch wide by an inch and a half long and cut it according to the illustration. Place a hairpin in the center, the length of the cardboard, and fasten it with tape that is adhesive on both sides. Bend to form an angle, as illustrated. Then attach behind the ear, one-half adhering to the head, the other half to the ear, forcing it out at an angle. Then model inside of the ear with nose putty, giving it the puffy appearance of a cauliflower.

Blocked-out teeth

The Teeth

In the ensemble of our features the teeth contribute much to the expression of the face. If they are discolored or too far apart these defects destroy much of what would otherwise be a pleasing expression. When teeth are too far apart the spaces may be filled in with gutta percha especially prepared for the layman's use. Discolored teeth can be effectively concealed by the use of tooth enamel, a preparation for giving teeth a uniform coloring.

Black tooth enamel, a quick drying film-forming liquid, is used to block out teeth for grotesque characters, such as old hags, witches, misers and comedy parts.

Your Make-up Materials

The amount of make-up material that is necessary to keep on hand will vary according to the purpose and interest of the amateur or experimenter, or the amount of work of the professional. Enough make-up should be on hand to complete whatever type or character you intend to portray, as the absence of a preparation would impair your success. Character requires a larger number of shades of grease paint, powders linings, etc. A complete list of the requirements for the Professional or the Amateur is as follows:

Grease paints, lining colors, face powders, lip rouge, dry rouge, under rouge, cold cream, clown white, burnt cork, nose putty, liquid make-up, black masque, white masque, tooth enamel, black tooth enamel, spirit gum, collodion, crepe hair, assorted shades, combs, scissors, chamois liners.

Make-up For Color Photography

The growing use of color in motion pictures places a further responsibility upon the make-up artist and the player using it. Since the day of the black and white picture is rapidly becoming shorter and color is coming more and more into use, greater attention than ever must be paid to tones and half-tones of color in make-up, and greater artistry will be demanded in this art. The following instructions are given for the use of make-up for natural color work.

Proper Method of Applying Technicolor Make-up

The first eleven steps in applying Technicolor make-up are exactly the same as given at the start of this article for applying straight make-up. However, in make-up for Technicolor, you have to consider dry rouge. This comes in the list of instruction directly after No. 11, Lip Effect, and is as follows:

Dry Rouge should be applied over the powder. A camel hair powder brush is ideal for this purpose. Apply the high points of the cheek bone first, then blend towards the nose and other points of the cheek, watching the contour of the face. Be sure that the edges are well blended and that no demarcation is noticeable around the eyes and mouth. Blend the rouge within the area of these lines; this will assist to eradicate the lines to a certain degree. For male types use rouge very sparingly.

Otherwise the directions for color make-up are the same.

Chart Suggesting Correct Shades of Make-up for Straight Technicolor Make-up

	Female Type	*Male Type*
Technicolor Grease Paint	D	D
Technicolor Face Powder	24	26
Technicolor Lining Color	21	21
Technicolor Moist Rouge	Light	Dark
Technicolor Under Rouge	Light	Dark
Technicolor Dermatograph Pencil	Brown	Brown
Technicolor Dry Rouge	Light	Dark
Technicolor Masque	Brown	Brown
Technical Liquid Make-up	D	D

Information concerning character make-up for Technicolor can be obtained by writing Mr. Factor at Hollywood.

A California Scene Elwood Bredell

PICTORIAL BEAUTY IN THE PHOTOPLAY

*William Cameron Menzies**

As AN art director I am interested in the photoplay as a series of pictures—as a series of fixed and moving patterns—as a fluid composition, which is the product of the creative workers who collaborate in production. As soon as the writer commences work on the scenario the composition of the picture begins. When the art director receives the finished scenario he begins to transpose the written words into a series of mental pictures. As he reads the script he visualizes, as nearly as possible, each change of scene, collecting in his mind the opportunities for interesting compositions. He sketches his settings with an eye to the action that will transpire and the emotional effect that is desired.

The director, when he places his characters and guides their movements, is composing pictures—still pictures and moving pictures. The costumer, the designer, the set dresser, the decorator, all contribute to the final composition. And last, but not least, the cameraman in the direction of his lighting and the determination of his different points of view, photographs the composition, to which many have contributed.

The photoplay as a pictorial art is unique in a number of respects. First of all, it is not an individual art, but rather is the product of a number of minds. The painter who paints a picture usually works alone, and his conception is his own. He alone is responsible for the color, technique, craftsmanship, and the spiritual something that he accomplishes. But the screen composition is the collective result of a number of minds working together. Secondly, our art is based on certain mechanical inventions, and is greatly dependent upon its mechanical and scientific resources. A piece of canvas, a dab of paint, and a few boards, often gives us a stage setting. Two or three of these and the requirements, as far as the settings are concerned for the stage play, are satisfied. The screen, on the other hand, offers many mechanical considerations and complications. Finally, other arts may or may not have universal appeal, whereas, our art *must* appeal to all the people. Our pictures are viewed by a larger and more varied audience than any other pictorial attempt. But this does not necessarily preclude the possibility of artistic achievement, for the truly great artists have been made great by the masses.

The photoplay of today reflects the tastes, habits and sentiments of the times. The pictorial beauty of the modern photoplay is an indication of the more general appreciation and the greater demand for beauty that is characteristic of modern life.

Automobiles are advertised for their beauty of line and color as much as for their mechanical efficiency. Henry Ford advertises

**Winner of the 1928 award of merit of the Academy of Motion Picture Arts and Sciences for outstanding achievement in Motion Picture Art Direction.*

beauty of line and color. This is true also of household furniture, and practically everything we use. The portable typewriters which you use are no longer just plain black machines, but they are now offered to you in various colors and designs. The manufacturers have suddenly awakened to the commercial value of beauty and are exploiting it. I think that the motion picture, through its representation of beauty in clothes, furniture, automobiles, and other features of our life, has been a vitally important factor in stimulating this new respect and appreciation for beauty that is noticeable. I know for a fact that many designers and illustrators see motion pictures for the inspiration and pictorial ideas they get from them.

The pictorial history of the photoplay is a history of the development of the public taste for beauty on the screen. This taste has been developed by tasting. One artist, in his efforts, has outdone the other, and the public continues, as always, to demand more and more. The artist who succeeds today must be able to give a wee bit more than his predecessors. Through cumulative progress the motion picture, with its tremendous resources, physical and human, will continue to blaze the trail for all other pictorial arts, and will assure our recovery from what has been referred to as "the ugliest age in history"—1850 to 1900.

In the earliest pictures, little, if any, attention was given to background. These were the novelty days, when the mere seeing of movement on the screen was sufficient to satisfy the public. The background was whatever happened to be behind the object or person photographed. The next step was a sort of travelogue background, using natural settings. As the pictures were done with a limited personnel, and in a short time, the backgrounds were not very carefully selected. In fact, it was quite usual for a company to go into the country in the morning with a camera, a couple of horses and an actor or two, and return in the evening with an epic of the period.

With the coming of stories demanding interiors the first sets had to be devised. These were originally, either a borrowed stage set, or a painted canvas backing. All the wall furniture, such as bookcases, pictures, was painted on a flat surface. Even vases with flowers, and chairs against the wall were painted, the only objects not being painted being those in the center of the room in actual use in the action. The company making the picture usually painted a trademark in a conspicuous place on the wall. For instance, Pathe used its rooster trademark in this way.

The sets were made of light framework and canvas, so that when an actor entered and closed the door the whole room, including the painted furniture, would shake. Usually these sets were set up outside and were lit by sunlight, giving a peculiar outside effect to a supposed interior. In addition the cameraman often had to pan up the camera to avoid showing the grass or dirt floor, and if a wind happened to be blowing, the actor almost had to hold his hat to keep it from blowing out of the scene. These early sets were designed principally by scenic artists or head carpenters, and often were planned or sketched on an old envelope, or the stage floor. In fact, an early designer of my acquaintance used to design his sets on the palm of his hand if nothing else happened to be handy. These early sets merely filled the requirements of entrance and exit; but in some cases they were surprisingly well done. The advent of the open stage did not help matters much, for, though the lighting was controlled by diffusers, or large overhead awnings, which could be rolled back and forth, the lighting throughout the scene would be continually changing with the movement of the sun.

As lighting equipment developed, the glass stage was abolished or darkened in, and all lighting was artificially created. At this time, artists and architects began to take a hand in designing sets. Texture, effect and composition began to be considered, and efforts were made to please the newly awakened taste of the public, which was growing more discriminating, now that the first novelty of the first motion picture had worn off. Gradually through the efforts of illustrators, painters, stage designers, architects, and commercial artists—all of whom had tried their hand at movie design, the set of the present day was evolved.

The set of today is neither a purely architectural nor a purely artistic product. It is an ingenious combination of art, architecture, dramatic knowledge, engineering, and craftsmanship. It combines in just the right proportions theatrical license with the reality of good architectural pattern. Simplicity and restraint are its chief characteristics. Simplicity is absolutely necessary for the audience must be able to grasp the whole scene and its meaning at a glance.

The orientation of exterior sets so as to take best advantage of the changing position of the sun presents many interesting problems. Your geographical location is a large factor in determining how you will lay out your set. You wouldn't do it the same in New York as in Los Angeles. It is usual to lay out a set to the south because back light is much better. Of course if you are going to shoot on the set all day you have to bear in mind the changing positions of the sun in relation to the changing action on the set. The declinations of the sun must be considered. I put up a set for Valentino's picture "The Son of the Sheik" which was supposed to be a desert palace or something of the sort. We didn't shoot the picture until three months later and had forgotten to take the changing declination of the sun into consideration; and the result was that the lighting was terrible—it was a complete back light, whereas we arranged it for a beautiful cross light.

It might be interesting to you to know how pictorial accomplishment has gone from one country to another. The original artistic pictures were mostly French, and for some time French cameramen and art directors were almost alone in the field. Then the Italians did "Quo Vadis" and "Cabiria," which were among the first artistic productions. Mr. Griffith made "Intolerance" and "Broken Blossoms," which for settings and photography created a new era in pictures. With the war America had the field mostly to herself and for several years most of the progress was here. After the war

Mr. Lubitsch's pictures such as "Passion" made in Germany, along with the lesser ones such as "The Golem" and "The Cabinet of Dr. Caligari," were very daring and different experiments. America again forged ahead with such pictures as "Ben Hur," "Robin Hood," and "The Thief of Bagdad," which Germany followed with "Variety," "The Last Laugh," and "Faust." In the last couple of years America seems to be leading again in artistic pictures such as "Seventh Heaven," "The Street Angel," and the very interesting work in "Our Dancing Daughters." "Sunrise" was made in America, but by a mixed German and American staff.

I would like now to discuss the importance of setting to the dramatic effect. First of all, the setting may be negative as in the old days when the background was often an irritating distraction. The setting may be neutral, in which case it neither adds to nor detracts from the effect. The setting may be designed with an eye to the intended effect, and may, in such a case, become a very important contributing factor. The setting might even become the hero in the picture, as would be the case, for example, in the filming of such a subject as "The Fall of the House of Usher."

The art director and the cameraman, with their many mechanical and technical resources, do a great deal to add punch to the action as planned by the director. For example, if the mood of the scene calls for violence and melodramatic action, the arrangement of the principal lines of the composition would be very extreme, with many straight lines and extreme angles. The point of view would be extreme, either very low or very high. The lens employed might be a wide angled one, such as a twenty-five millimeter lens which violates the perspective and gives depth and vividness to the scene. The values or masses could be simple and mostly in a low key, with violent highlights.

In a scene such as the one to which I have just referred, when the tempo of the action is very fast, there are usually rapidly changing compositions of figures and shadows. For idyllic love scenes, or scenes demanding beauty, the values and forms are usually softer, the lens is diffused and the grouping and dressing graceful and lyrical. In the case of pageantry such things as scale and pattern, figures, rich trappings against a high wall, through a huge arch are demanded. In comedy scenes the composition may be almost in the mood of caricature. In tragedy or pathos, or any scene photographed in a low key, the setting is often designed with a low ceiling, giving a feeling of depression.

The set itself causes a laugh. I recall in Corinne Griffith's picture "The Garden of Eden" a place where a couple starts an argument after they are in bed and every time they sit up to argue they turn on the light. There was a man living across the court and he noticed the light going on and off and thought somebody was signaling and begin to flash his light on and off. Then other people saw it and did the same. We made a miniature of the complete side of a hotel and all the windows were flashing lights. It caused a great laugh.

Thus we see that the design of the setting and lighting may become a very important element in the securing of any desired emotional effect, and this explains why, in many cases, authenticity is sacrificed, and architectural principles violated, all for the sake of the emotional response that is being sought. My own policy has been to be as accurate and authentic as possible. However, in order to forcefully emphasize the locale I frequently exaggerate—I make my English subject more English than it would naturally be, and I over-Russianize Russia. An interesting thing happened when I was working on a Spanish picture with Miss Pickford quite a few years ago. We had to have a Spanish city near Toledo and I put the Campanile of Toledo in to make it authentic. As you know, Madison Square Garden in New York has copied this campanile, and so many people recognized it and asked what Madison Square Garden was doing in the picture, that I had to change it.

It might be interesting for you to go through the routine of the art director's work from the moment he receives the script. In the first place, although not customary, it is of great advantage to the art director to know something of the story as it is being constructed. Very often he will have many valuable suggestions to offer. Now, what I am describing is my own method. Except for some slight variations, I think most of the art directors follow the same method. When reading the scenario, notes are made, and if there is sufficient time, rough sketches of the separate scenes are prepared. After consultation with the cameraman and director and the incorporation of their suggestions, the art director works up his sketches into presentable drawings. He considers such things as point of view, nature of the lens to be used, position of the camera, and so forth. If he is concerned with intimate scenes, he concentrates on possible variations of composition in the close shots. If he is designing a street, or any great long shot, he considers the possibility of trick effects and miniatures, double exposures, split-screens, travelling mats, and so forth.

When the drawing is finished the director, cameraman, and designer confer again, and when all interested are satisfied with the drawing, it is projected through the picture plane, to plan and elevation. However, this process reproduces the composition line for line, and retains all the violence or dramatic value of the sketch, even with changed point of view. The finished plan and elevation is blue printed and sometimes transposed into a model and turned over to the construction department.

From then on the artist's main interest is the supervision of the texture and painting of the set. Texture is a rather interesting subject. All our straight plaster textures are cast in sheets nailed to a frame, and then pointed or patched with plaster. Brick, slate roofs, stone work, and even aged and rotted wood are casts taken from the original thing, made in sheets and applied. That is, if we have a stone wall, we get in a lot of stone and build up a wall about six feet high, put the plaster cast on it, and peal it off like you do a cast from a tooth. You can cast any number of pieces of wall from that. The painting is usually done by air guns, and in many cases the light effects are put on by expert air gun operators.

As much as it possible, now-a-days, everything is shot on the lot. Forests, ships, country lanes, mountains, canals, and all, are built up and tricked so that what, on the screen, may cover miles of ground, in reality only occupies a few acres of the back lot, or a few hundred square feet of the stage.

Sometimes we have to resort to optical illusions. In the "Thief of Bagdad," Douglas Fairbanks wanted to swim under water to find a pearl or something, on the bottom of the ocean. We took a set and cut out seaweeds of buckram, and had a series of them hanging down in several places. A wind machine was put on so that seaweeds flapped, but as the scene was taken in slow motion, they undulated when shown on the screen. The camera had a marine disc over the lens and was turned over. Mr. Fairbanks was let down through the scene and went through the motions of swimming under water. The scene had the appearance of water and gave almost a water feeling. It was a very interesting effect.

In this same picture we had the problem of photographing Mr. Fairbanks on a flying magic carpet. We got a ninety foot Llewellyn crane and had the carpet suspended on six wires. There was Doug hanging on six wires he couldn't see. They were each guaranteed to hold four hundred pounds, but he said, "I would like something more than a guarantee in a place like this." When the beam was started, the carpet would be left behind a little until the slack was taken up and it gave us quite a thrill each time it was started. We also had to arrange for a traveling camera (which by the way is another thing that an art director is involved in), and had a platform built for the cameraman which travelled with the crane. That was the first travelling shot. Of course today they have complicated machinery for this purpose. For instance in "Broadway," they had equipment for moving shots which cost thousands of dollars to build. The Fox company has a lense they can use to bring a person from a long shot up to a closeup which saves a great deal of expense.

As an illustration of the advance made in this matter of getting trick shots, I might mention my first experience in pictures. When I got out of art school I went to see George Fitzmaurice to get a job, and he tried me out. The studio where his pictures were made was in Fort Lee, New Jersey, across the river from New York. For one of his pictures he wanted a close-up in a tropical setting. Now here in California there are plenty of palm trees and you would have no difficulty, but in Fort Lee, New Jersey, there is nothing of the kind. The only thing I could find was a couple of palm leaf fans. I stripped them down to palms and to secure my effect, stood on a chair in the sun, waving the palm leaves so that the shadow was thrown on the wall back of the actors.

So you see the motion picture technician must have great ingenuity. He must have a knowledge of architecture of all periods and nationalities. He must be able to picturize and make interesting a tenement, or a prison. He must be a cartoonist, a costumer, a marine painter, a designer of ships, an interior decorator, a landscape painter, a dramatist, an inventor, an historical, and now, an acoustical expert—in fact, a "Jack of all Trades."

A word about the cameraman and the importance of his work. The development of photography has kept pace with that of the set. The cameraman has brought his work to a fine art. His equipment has become much more complete, and he too, has become a specialist. He does the actual photographing, which means that he has been handed the results of the previous workers, and through his photography he has great possibilities for good as well as harm to the picture. His responsibility is a grave one and the art director can often aid him by properly designing the sets. The cameraman must see that the star is photographed to her best advantage. Close-ups are the most difficult because the accentuated dramatic action and their composition and lighting must be perfect. He must see that the desired pictorial effect is obtained from the scene as a whole. He must take infinite pains with his lighting and his composition, and he must carefully watch the development of the film. Many times the cameraman, after a twelve hour day, has to go over to the laboratory and watch his negative and time its development himself, because if the negative is overdone or underdone, his photography will suffer. You have to be careful that the film is neither too light nor too dark, or it scratches when run and then after it has been run six or eight times it is full of scratches and oil. If it is in a medium key you don't see it so much. If extremely low or extremely dark, it is full of holes and flashes and everything else.

Not only must he do these many things, but he usually has to do them under pressure of time. He must select his compositions with very little previous study. He must light for continuous and changing movement, rather than for one beautiful picture. He must sacrifice for visibility many lovely light effects in low keys. He must remember that the film will be run many times, and by projectionists of all sorts, so that what constitutes beautiful soft photography in his projection room, may look very poor when handled by the projectionist in some small Arkansas village for instance.

The advent of the talking picture, as you realize, disturbed the craft in all branches of motion picture production. The addition of speech has, possibly, made the reliance on pictorial values a bit less vital. History seems to be repeating itself. Just as the novelty of movement on the screen was sufficient to hold the first audiences, so the novelty of hearing people talk on the screen was at first important enough to satisfy the curious audience. Pictorial beauty, so far as the first talking pictures were concerned, was noticeable by its absence. The public soon began to feel this. There was something lacking, and that something was that pictorial beauty that was in a very subtle manner an important element in the silent picture.

The talkies are no longer a series of mere pictures of people speaking lines, but are rapidly bringing back all of the values, all of the beauty, of the silent motion picture, with sound and speech as a supplement. "In Old Arizona" was probably the first talking picture that did not ignore pictorial beauty. I think that this accounts, to a great extent, for its tremendous success. Several others have had some pictorial interest, but the ultimate in a finished, artistic talkie has yet to be made.

The acoustical demands in connection with the production of talking pictures have had a very noticeable effect on the design and the construction of the settings. Too much plain hard surface cannot be exposed unless of a very soft and absorbent texture. We are making very many of our sets of cloth, or a very porous wall paper. Hollow, tunnel-like cavities must be avoided. Also, the set in talking pictures, must be lit for long shots and close-ups, which are shot at the same time. There are fewer sets, but more of what might be called single shot effects. A set prepared for a short and long shot looks almost bare to the eye, but when seen on the screen it has a habit of muddling together. For instance, if the pieces of furniture are close together they look like one mass and you cannot tell what it is. Therefore you have to use them sparingly. The arrangement of the set must also be different for different lenses. A wide angle lens will throw the thing back, which will simplify it and give it depth and you can naturally have more furnishings; but a narrow angle lens will jam it all together and consequently you must have a greater distance between the furnishings in the set.

I think that the addition of speech has been a great step forward. And, with the addition of color, stereoscopic perspective, and possibly a variety of shapes to the screen proportions, we will have attained almost reality itself. The subject of stereoscopic perspective on the screen has been brought up thousands of times. Many think it is impossible because everyone cannot look at the screen from the same focal point. I was talking to an eye specialist from Johns Hopkins University and he seems to think he has got it. If he has, it is a tremendous thing and will change the proportions we are now using.

As I have suggested here the pictorial quality of the motion picture rests largely with the public. Douglas Fairbanks spoke a great truth when he once said: "Better films will come when appreciation for better films is developed. It is appreciation and criticism which guides the artist."

The producers, like many other manufacturers, have awakened to the fact that beauty is efficiency, and that good art is usually good business. They have found that the public is no longer satisfied with the settings, costumes, lighting, and groupings of last year, or yesterday. They have learned that pictures must be well composed, for a well composed picture is one at which the audience can look at and see a lot with ease. The eye and the attention of the spectator is attracted to the right point and directed in accordance with the demands of the story. Somehow the idea has crept into many minds that the artistic picture is destined to be unpopular. However, I think that if you will look at the matter fairly you will find that where artistically composed pictures have failed, they have done so not because of beauty, but because of lack of some other necessary attribute.

This paper was read before a class in appreciation of the Photoplay, at the University of Southern California; a course conducted in conjunction with the Academy of Motion Picture Arts and Sciences.—The Editor.

PHILOSOPHY OF MOTION PICTURES

*George O'Brien**

SUCCESS in any phase of life is usually attained with the combined efforts of co-operative forces whether it be motion pictures, railroads, or football teams. We who are actually part of the team responsible for making a goal, which will be converted into another tally called 'victory', or, I should say, 'box-office success', continually hear the call for good stories. A good story is always welcomed by director, interested cast, and cameramen. With the proverbial word known as 'meat' in a story the director may work with a situation until he, the cast, and cameramen have satisfied themselves that they have given all that the sequence or sequences called for. But, if the work is not properly handled by the camera-crew the efforts put forth are wasted. On the other hand, if given poor material the director exhausts himself trying to inject highlights into the story, tears down the otherwise smooth characterizations the players may try to offer, and their efforts are hardly worth the expense of photographing.

Keeping up the morale of a troupe is quite essential in producing a successful picture either on location or in the studio. A good story often plays a big part in keeping up the morale. In my own experience I have found the camera-crew, at the start of the picture, as well up on the situations of an interesting story as the director and cast. This, of course, should be the rule always, as a story that interests its producing unit will create greater enthusiasm and spur its workers on to unlimited heights of creating new effects of lighting and other forms of artistic endeavor, which, after all, promotes harmony. This sort of spirit which is not impossible to develop as it is being practiced among many well known producing units seems to travel like wave-lengths in the air. The publicity and exploitation departments take up the spirit in turn and find themselves not only boosting but bragging about their product. The producers and financial executives who gamble to find such spirit very often delight the enthusiastic crew by allowing more time on the schedule and more money for the budget. The salesmanagers and salesmen learn of the enthusiasm put forth in the production, and with an honest effort to satisfy the exhibitor they encourage him to preview their product, which results in a 'box-office success'.

Each individual, the director, the members of the cast, the camera-crew, and all up and down the line of motion picture producing units feel that the production could not be a success without their efforts. Individual effort would mean nothing. Each person co-operating in their particular line produces splendid pictures which spell success at the box-office.

* *Fox Star.*

WIDE FILM DEVELOPMENT

Paul Allen, A. S. C.

ONE of the outstanding developments of the past year in the motion picture industry has been the introduction of wide film. Even the advent of sound created no greater flurry of excitement than has the wide film problem. And now, even though the public has been permitted to view one of the results, no one seems to have any definite idea as to what the future will bring forth in the way of a standard size film. One thing seems certain—that we will have a standard film wider than the present standard of 35 millimeters. What the width will be is a problem.

Advocates of the 70 millimeter, Fox Grandeur, are proclaiming that width as the perfect one. But there has been a considerable swing to the idea that 65 millimeters will be the perfect width for the new standard. However, there is quite a move on foot at this writing to bring about a compromise on a standard width of 68 millimeters.

Perhaps it would be proper at this point to briefly sketch the early history of wide film, because, while the majority of people think wide film is something new, it is, in reality, a revival of what took place far in the past. This is a natural conclusion to draw, however, because the standard width of film, 35 millimeters, has become so widely accepted that one often hears of it as the only standard of measure which is common to all nations.

Today the producers are surrounded by a veritable chaos, as far as film width standard is concerned. And so it was back in the nineties. Today the producers realize that a larger film must come in the not distant future, and naturally, there is an effort being made to find a width which will be fixed as a standard. In the nineties the same situation existed, and film was being used which ranged in width all the way from one-half inch to 70 millimeters.

Perhaps the best idea of what was happening then may be found in an excerpt from Carl Louis Gregory's article on the early history of wide film, which he read before the S. M. P. E., which reads in part:

"An advertisement in Hopwood's 'Living Pictures' edition of 1899 offers the 'Prestwich' specialties for animated photography—'nine different models of cameras and projectors in three sizes for ½-inch, 1⅜-inch and 2⅜-inch width of film.' Half a dozen other advertisers in the same book offer 'cinematographs' for sale and while the illustrations show machines for films obviously of narrow or wide gauge no mention is made of the size of the film.

"During 1899 there were in England and on the Continent Mutograph films 2¾ inches wide; Demeny Chronophotographe 60 mm. wide, Skladowsky film 65 mm. wide, Prestwich wide film 2⅜ inches wide, Birtac films 11/16 inch wide, Junior Prestwich

½ inch wide, besides the present standard established by Paul, Edison and Lumiere.

"Henry V. Hopwood in 1899 described more than fifty different models of projectors made by different manufacturers and gives the names of about seventy more. Curiously enough the size of film used in the various machines is mentioned only in two or three instances. It is probable that most of them used the Edison standard of 35 mm., although it is obvious from the descriptions that many of them used other sizes.

"Probably the first example of motion picture 'film' as it is photographed today was a scene taken in the Champs Elysees in Paris in 1886 by Dr. E. J. Marey. Although the 'film' was paper, sensitized celluloid not being available until a year or two later, and cine projectors having not yet been invented; this paper negative could be printed as a positive film and run as a Fox Grandeur film today.

"In May, 1889, William Friese-Green, 92, Piccadilly, London, made a motion picture negative of a scene on the Esplanade, Brighton, England, using paper film negative 2½ inches wide and 1½ inches height to each frame. Later in the same year he used celluloid film displacing the paper used earlier.

"One of the first to project successfully upon a large sized screen was Mr. Woodville Latham, inventor of the Latham Loop which caused much patent litigation in the early days. Latham called his machine the Eidoloscope and used wide film 2 inches wide with frames ¾-inch high by 1½ inches long.

"Oval holes cut through the frame line at each side alternately served to make electrical contact to light the arc each time the intermittent brought the picture to rest. This intermittent lighting of the arc served in place of a shutter but was not very successful as the electrical spring contacts scratched the film and the arc responded irregularly to the quick make and break.

"In the fall of 1897 Enoch J. Rector, an inventor and promoter, showed pictures of the Corbett-Fitzsimmons prize fight in the Academy of Music on 14th Street in New York City. His apparatus was called the Veriscope and the same mechanism used to show the pictures was employed in the camera with which 11,000 feet of film were taken at Carson City, Nevada, March 17, 1897. Thereafter about twenty machines for projecting this large size film were manufactured and these fight films were exhibited all over the country.

"In the late 90's the motion picture was regarded as a great novelty which would soon die out. Conditions were chaotic and everyone who went into the business worked with frantic eagerness to reap the rich harvest before the fickle interest of the public should pass on to some new fancy.

"Just as there was no standard of film size, no rate of frames per second was established and the taking rate varied from 8 per second to 60 per second among the different systems, each of which was distinguished by some fantastic and polysyllabic name. Out of the hundreds of such coined trade names only a few are remembered today; such as Kinetoscope, Vitagraph, Biograph and Mutoscope.

"Subjects were confined almost entirely to news events, prize-fights, short scenic shots and theatrical or spectacular bits, many of which were considered very risque in those conservative days. The May Irwin Kiss, Little Egypt, Loie Fuller's fire dance, Bridget Serves Salad Undressed and many others brought gasps of amazement at their audacity.

"On November 3, 1899, the Jeffries-Sharkey fight was held at Coney Island at night. Wm. A. Brady, now well known in the theatrical and motion picture world, and a promoter named O'Rourke sponsored the bout and induced the American Mutuscope and Biograph Company to film the fight.

"The film used was 2¾ inches wide and each frame was 2¼ inches high. Three hundred and twenty feet of this wide film was used per minute, the perforations being made in the camera at the instant of taking.

"The fight lasted for twenty-five rounds of three minutes each and more than seven miles of film were exposed. Four cameras were on the job so as to obtain a continuous record. Buckling of the film in the cameras was frequent although the film could be watched through a red glass peep-hole by the light of a small ruby lamp inside the camera box.

"The perforations in the large Biograph film were used in printing but not in projecting. The projector pulled the film down by means of a set of mutilated rubber rollers and the projectionist had to watch the frame continuously to prevent creeping of the frame line on the screen.

"Oscar B. De Pue, partner of Burton Holmes, in 1897, purchased a machine in Paris from Leon Gaumont for taking 60 mm. wide film then put up in one hundred foot lengths, unwinding and rewinding inside the camera on aluminum spools; not a daylight proposition, but a dark room model. This machine he took to Italy and the first motion picture turned out on the machine was of St. Peter's Cathedral with the fountain playing in the foreground and a flock of goats passing by the machine. He then took other pictures of Rome and from there visited Venice, where pictures of the canal and Doges Palace and the waterfront along the canal with views of feeding the pigeons at St. Marks with the great cathedral in the background. From there to Milan for a scene of the Plaza in front of the Milan Cathedral; thence to Paris where pictures of the Place de la Concord with its interesting traffic and horse-drawn busses, fountains, obelisks, statues, bicycles, wagons, trucks and carriages were made. All the life of that day, after thirty-two years, is in striking contrast to the present.

"These negatives are still in his possession although the prints for them have long since been lost track of on account of our having changed from that size of picture to the standard size.

"This Gaumont wide film camera was used for five years by Mr. De Pue and most of the negatives, many of which are of great historic value, are still in good condition, so that either full size or standard sized reduction prints can still be made from them.

"Spoor and Bergren have worked for more than ten years upon a 63 mm. film called Natural Vision pictures.

"Widescope first sponsored a double frame picture on standard film with the film travel horizontal instead of vertical; after that an Italian patent was acquired in which a wide film of about 2¼ inches width is held in cylindrical form about the axis of rotation of a revolving lens so that the succeeding frames are photographed on the same principle as in a panoramic still camera. Unfortunately this method of taking pictures introduces the same curvelinear distortion often noticed in circuit and other panoramic still photographs."

At present extensive work is being done in the Fox Case Grandeur in 70 millimeters; Spoor-Bergren in 63 millimeters; still another is 56 millimeters, and Ralph Fear of the Fearless Camera Company has brought out a new camera for photographing on 65 millimeters, which one big picture company is now using in a production. Several of the other large studios are said to be turning a very favorable eye towards this width.

While there has been much in a general way published regarding these various width films, the producing companies apparently have been somewhat loathe to give much detailed and authentic information. From Paramount, where experiments have been conducted in 56 millimeters, there is practically no information available. RKO has issued much publicity regarding contemplated use of the Spoor-Bergren 63 millimeter film, but recent rumor has it that this concern is planning to take up the 65 mm. size.

However, there is a little more information available regarding the 70 millimeter film of the Fox Grandeur. This company has already presented this width to the public, and as a result of this and the advantages shown in the use of a film wider than the present standard of 35 millimeters, it is pretty generally agreed that a wider film than the 35 millimeter will be evolved out of the chaos.

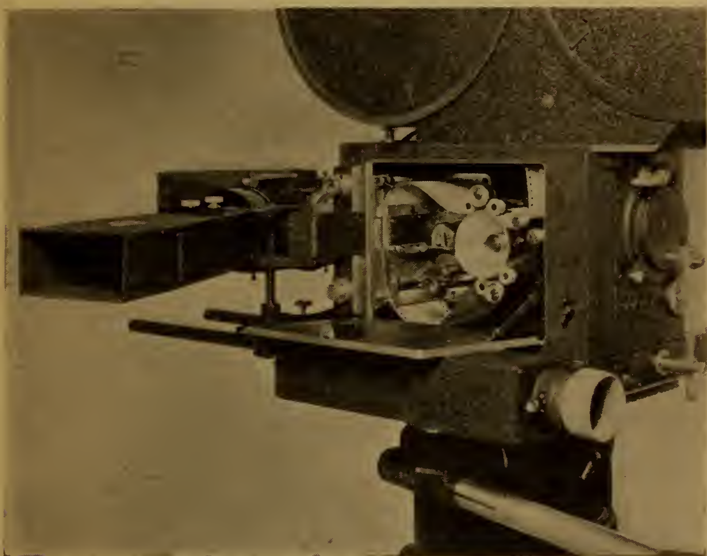
In the case of Grandeur, the Fox film, the width of the film itself is 70 millimeters; while the frame is 22½ millimeters x 48 millimeters; leaving a sound track 7 millimeters wide in the customary position at the left of the picture.

The only difference between the normal film stock and that of the Grandeur is that the Grandeur is cut in wider strips and the perforations are of a slightly different pitch. Eastman is the only firm at present making the 70 millimeters width film, and the only perforators for this width film, at this writing, are found in the Eastman plant at Rochester.

The cameras used are made by the Mitchell Camera Company and are available on the open market. They are simply the standard Mitchell Camera enlarged laterally to accommodate the wider film. Wherever possible the parts are interchangeable with those of the 35 millimeter, and the design has been such that this is a surprisingly large number of cases.

The most outstanding changes are found in the shutter, which had to be made practically double the size of the old one, and in the actual film-moving mechanism. The gears of the Grandeur-Mitchell are cut differently, as the pitch of the Grandeur perforations is approximately .231″ against a pitch of .87″ for the 35 millimeter standard. In all other respects the 70 millimeter Mitchell is identical with the 35 millimeter. Special Grandeur lenses having a greater angular covering power are used.

Grandeur projectors are being manufactured by the International Projector Corporation, and many of the major Fox theatres are



The Mitchell 70 mm. camera for making Grandeur pictures.

being equipped with them, and according to the present plans of that organization all the Fox houses will ultimately have this equipment.

What are the advantages of a wider film?

The present standard of 35 millimeters was arrived at purely by chance, as Mr. Gregory pointed out, being largely due to the coincidence that the standards independently arrived at by Edison and Lumiere coincided to within 1/1000 of an inch. This width film gave a frame of 18 mm. x 23 millimeters, and when the great theatres of the present came into being with colossal throw and large screen, a tremendous enlargement of this tiny picture was necessary. This can be done only to a certain point, and then the matter of grain interferes.

Then, too, the exigencies of sound pictures added another problem. The addition of the sound track to the film reduced the already too narrow frame. The advent of the stage revue type of picture also called for something larger than the 35 millimeter and the size screen used for it.

Even before the coming of sound, many cinematographers, directors and laboratory men thought the standard four-to-three proportions of the frame was too high in proportion to width to be artistically correct. With the addition of the sound track this frame

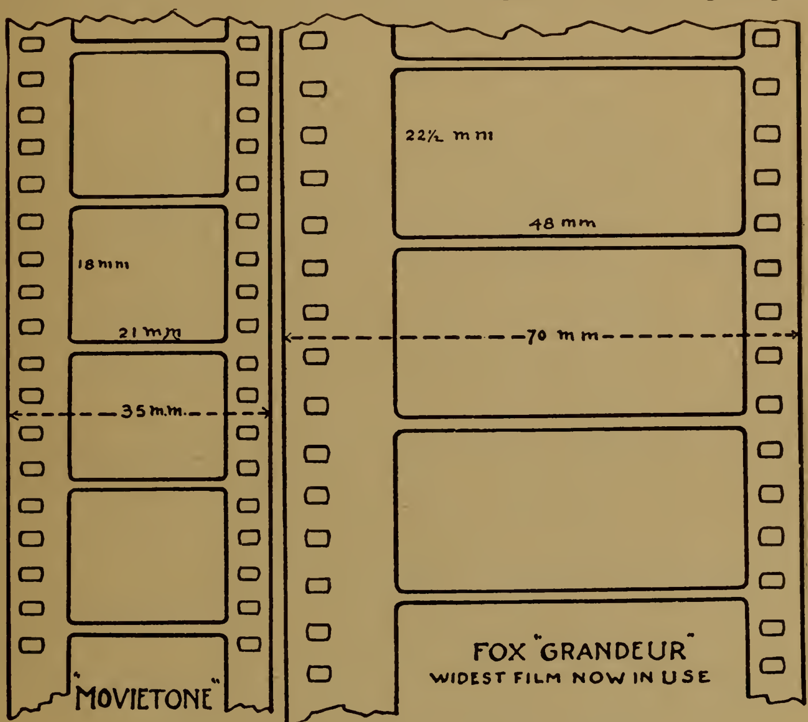
Actual size Grandeur scene from "Happy Days."

was reduced to almost a square and there has been much effort on the part of theatre owners and others to restore even the old rectangular proportions by means of shorter focus lenses and reduced projector apertures.

It was with the thought in mind to create a size film that would be more satisfactory for use in sound, and one which would give a greater picture on the screen, with an angle of greater width, that the Fox company started experiments which finally resulted in the Grandeur film.

From a practical viewpoint the Grandeur offers many practical advantages over the 35 millimeter. The director can film his spectacular scenes and dancing numbers with fewer cuts and no closeups. The cameraman has greater scope in his composition and much advantage in his lighting. Back lighting under the 35 millimeter conditions since sound came changed the proportions of the frame has been difficult.

However, the Grandeur and Cinematographer's task is lightened inasmuch as the sets need not be so high, and back lighting at



Comparative size of Grandeur and Standard Movietone film.

effective and natural angles is possible. Direction of expansive scenes is simplified, for the proportions of the 70 millimeter frame, 22½ mm. x 48 mm. are such as to give ample scope for all movements with adequately large figures. Dance scenes need not be followed, for there is plenty of room for them in normal long shots. Composition with this film does not present the difficulties of 35 millimeter. The angular field of view of the various lenses are different, naturally. The comparisons here shown of angles included by representative lenses on standard film with a frame of 19 mm. x 25 mm. (standard), and Grandeur with its 22½ mm. x 48 mm. frame are interesting.

Focal length of lens	*Standard Film*		*Grandeur*	
40 mm.	42°	52′	65°	28′
50 mm.	34°	52′	54°	26′
75 mm.	23°	38′	37°	50′
100 mm. (4″)	17°	50′	28°	50′

Photographers who have used Grandeur recommend use of a lens approximately 2/3 longer in Grandeur than in 35 millimeter.

Sound men should be interested in Grandeur for it gives them a sound track 7 millimeters wide as against 2 millimeters of the standard. This naturally permits much greater volume-range in recording and gives a better quality. This in either Variable Density or Variable Area processes, but particularly in the latter.

The projectionist receives much from Grandeur, also, for the projector for Grandeur use has many features particularly pleasing to the operator. Chief among them is the fact that the film runs cooler than standard, for the shutter is between the light source and the film.

The audiences thus far appear to have taken to the wide film, too. They receive many thrills in watching pictures made on this width. Chief among the outstanding audience features is the effect of pseudo-stereoscopic depth that is displayed. It makes for more naturalness in the picture. The wide proportion removes the consciousness of the dead black borderline. Strangely enough, there is an absence of grain unless you get very close to the screen.

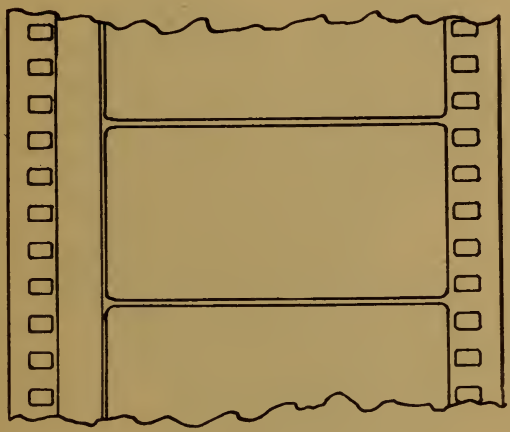
So much for Grandeur. It is here, and has its advantages. Whether or not it will be accepted as a standard is a question no one at present can answer.

Mr. Fear, inventor of the new Fearless 65 millimeter camera, which is being used in actual production by one big company, claims that he has the ideal width. And there are many in the picture industry who agree with him. We will not dispute him; neither will we dispute the Fox organization, nor any of the others who are experimenting in an effort to arrive at a film width that will add to the development of the industry. We are only attempting to set down the facts as we find them. Thus far this writer has not seen any film shot in 65 millimeters, but it seems very probable, in fact it must be so, that the 65 millimeter width has tremendous advantages over the 35 millimeter standard of the present.

The fact that one of the largest producing companies in the industry is using this camera at this width indicates that there must be a lot of merit attached. Also the fact that several other large companies while not publicly announcing their plans are known to have decided upon the use of 65 millimeter width film would indicate that the final decision as to a new standard lies practically between the 65 millimeter and the 70 millimeter widths. Mr. Fear declares the 65 millimeter width is "the ideal width for perfect picture reproduction."

As in the case of the Grandeur film, the 65 millimeter width gives the great advantage of a wider sound track, which naturally, makes for better tone quality and greater volume-range in recording. Then, too, in the matter of the "frame," the 65 millimeter has advantages over the 35 millimeter standard that has been breaking the hearts of the cameramen for months. The "frame" of the 65 millimeter width is 22 mm. x 45 mm., which is claimed by Fear and those who are advocating 65 mm. width to be the ideal frame size for perfect reproduction on the screen. The same claim to stereoscopic depth that is visible in the Grandeur is claimed by Fear and other advocates of the 65 mm. width. Fear also claims that the 65 mm. film is of such size that the lens covers the entire field, which is one of the problems in the use of the 70 millimeter width.

As Mr. Fear's new 65 millimeter camera was not introduced when the article on cameras was prepared for this publication we



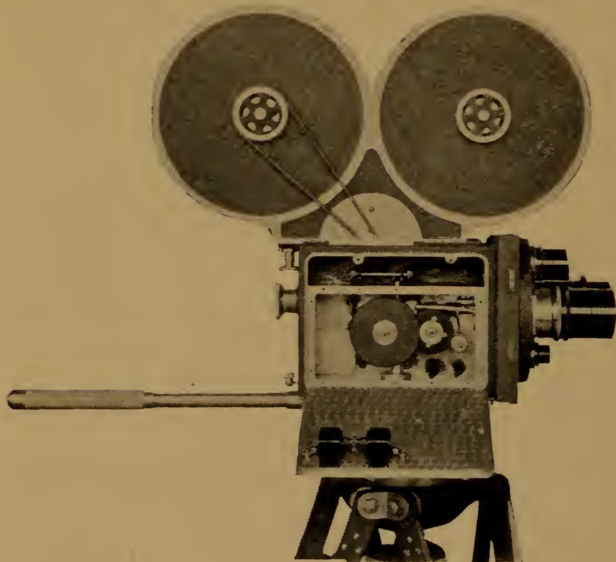
Actual size of the 65 mm. film.

feel that it will be well at this point to give a few details of the camera for this width at this time.

From the cameraman's point of view, the most interesting feature of this new camera is the fact that it may be used for either 35 mm. standard or for the 65 mm. film. It is normally built for use with 65 mm. But a special movement has been constructed for 35 mm. use, and is interchangeable with the 65 millimeter movement— requiring only a few minutes' times for the change. Two interchangeable sprocket and roller assemblies have been developed. So, by merely removing one movement and substituting the other the camera is interchangeable.

When the Fearless camera is purchased for 65 mm. superfilm or for special size wide film, the accompanying magazines are designed so that 35 mm. film can also be used in them. This is accomplished by providing the film rollers with a relief so that the 35 mm. film is properly guided into the magazine and by furnishing special take-up spools for the narrow film. These spools hold the film central in the magazine and prevent it from creeping to one side or the other. In fact they practically act as a film reel.

Standard 35 mm. magazines can also be used on the camera when using 35 mm. film; thus making it possible to use some of the equipment that the producer now has. This is accomplished by making a special adapter which fastens on top of the camera. This adapter partially covers the hole for the large size film and excludes all light from the inside of the camera when using the 35 mm.



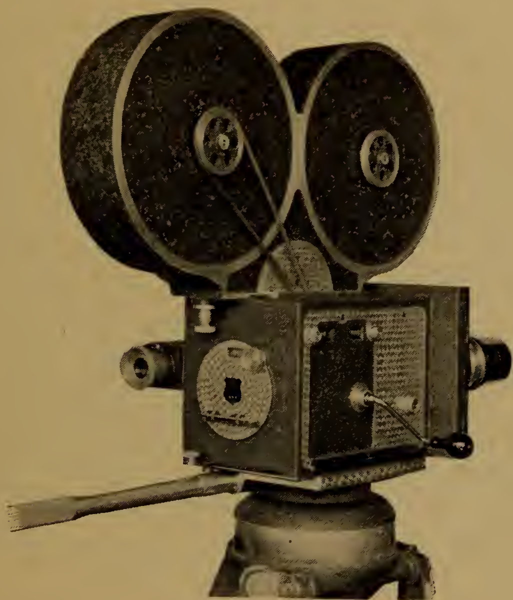
Fearless 65 mm. camera, showing mechanism in oil-tight and sound-proof compartment.

magazines. With the adapter in place, standard 35 mm. magazines can be used.

Other features furnished as standard equipment in the new Fearless camera include a quick focusing device; full force feed lubrication to all major driven parts, all driving parts being inclosed, and running in an oil bath; and two built-in footage counters. As special equipment the camera can be furnished with a built-in speedometer, a built-in three-speed high-speed gear box and a built-in sound recording mechanism.

To elaborate on the method of focusing the photographic lens— The camera is built with a sliding turret and lens carrier on the front of the camera box. This lens carrier is mounted in dove tails and constructed so that it may be shifted across the front of the camera box to a point where the photographic lens is in front of the ground glass of the focusing tube. The lens carrier is made so that the light shade is mounted to it and instead of having to shift the camera, magazine, motors, cables, etc., only the light weight lens system and light box is shifted.

The actual shifting is accompanied by merely pressing down a knob and moving a lever from one side of the camera to the other. This focusing operation is performed so quickly that it has been a revelation to all who have seen it. Suitable stops prevent over-travel and suitable locks are provided to hold the lens carrier either in the focusing position or in the photographic position. The



Rear and right side view of the new Fearless 65 mm. camera.

image is viewed with a conventional finder or focusing magnifier which is supplied for either five or ten power. The focusing telescope is of the simple astronomical type, and re-inverts the inverted image formed by the lens on the ground glass, thus bringing the viewed image right side up and right side to.

The Fearless camera can be furnished with built-in auxiliary recording aperture at the proper distance from the photographic aperture and sprocket for recording sound directly in the camera. The auxiliary sprocket for pulling the film past the sound recording aperture is driven by a mechanism designed to absorb vibration so that the sound recorded is free from the so-called wow-wows caused by irregularity of film speed by the sound aperture. This feature of built-in sound recording makes it possible for the producer to make sound pictures at once without having to wait for new recording apparatus for the new size film. The design is adaptable to almost any type of light valve or glow lamp type of recording.

A standard Fearless Silent movement of enlarged size is used to feed the film intermittently past the aperture. Two claw pins are used on each side of the film to pull the film down and pilot pins are used to lock the film during the exposure. This movement is extremely easy to thread and due to simplicity of design and accuracy of workmanship is so silent that only by placing the ear against the frame of the movement can any sound be heard while in operation.

The camera has been designed for silence and extreme pains have been taken in the design and construction to eliminate noise

Right side of new Fearless 65 mm. camera, showing oil tank and footage meter.

wherever possible. The camera can be used in the open for all ordinary shots without any sound proof coverings, according to the claims of Mr. Fear. This has been accomplished by using fibre gears to transmit the power, precision bearing for the driving shafts, and by inclosing all moving mechanism outside of the movement and sprocket assembly in an oil tight and sound proof compartment which serves as an oil reservoir. An oil pump within this compartment pumps oil to all bearings and moving parts therein. This circulating oil deadens any noise developed by the mechanism. The oil level may be viewed through a window built into a plate that covers the mechanism compartment. Sufficient oil is placed into the compartment to last for several months. All high grade automobiles use pressure feed lubrication, but this is the first time it has been applied to a motion picture camera.

The motor drives directly into an extension of the movement cam shaft, and thus transmits the motor power directly to the most highly stressed part of the camera and eliminates a great deal of noise caused from gears. The motor itself absorbs any vibration caused by the intermittent movement.

Silent bakelite gears are used to drive the sprockets and shutter shaft. A large heavy shutter of the two opening type running at a speed one-half of the intermittant mechanism is used for a fly wheel. This heavy revolving shutter also absorbs any noise that might be transmitted to the front of the camera. Wherever possible instrument type precision anular ball bearings have been used to reduce friction and to insure long life to the camera. Two footage counters of the Veeder type are built into the camera, one being used for total footage shot and the other being used for individual takes.

So, there is the situation as it exists at this writing.

Undoubtedly there will be some concerted effort during the coming year to bring about a standard. This writer's opinion is that it will be either the 65 millimeter or the 70 millimeter.

Sails

Karl Struss, A. S. C.

Through the Bridge — Karl Struss, A. S. C.

Dance Study Karl Struss, A. S. C.

The City of Dreams — Karl Struss, A. S. C.

Landscape — Fred Archer, A. S. C.

In Old Clamecy

Fred Archer, A. S. C.

APrayer to Isis

Fred Archer, A. S. C.

The Fisherman and the Genii — Fred Archer, A. S. C.

Modern Design — Fred Archer, A. S. C.

Reflection Study Fred Archer, A. S. C.

Posing — Fred Archer, A. S. C.

The Hunt — Bob Roberts

Sunset

L. Guy Wilky, A. S. C.

Wreck L. Guy Wilky, A. S. C.

Palms L. Guy Wilky, A. S. C.

Papeete L. Guy Wilky, A. S. C.

Out of the Fog — Elmer G. Dyer, A. S. C.

Waterfall Elmer G. Dyer, A. S. C.

Rivulet **Elmer G. Dyer, A. S. C.**

Dog Fight — Elmer G. Dyer, A. S. C

The Dawn Patrol — Elmer G. Dyer, A. S. C.

Snowy Roofs — Elmer G. Dyer, A S C.

Home **Elmer G. Dyer, A. S. C.**

Alone — Elmer G. Dyer, A. S. C.

Composition of Arches — Jack Landrigan

Explorers Bob Roberts

Crack-up

Francis J. Burgess

Mermaid

Otto Dyar

Snow Man Fred Archer, A. S. C.

The Harbor William Stull, A. S. C.

Drowsy Canal William Stull, A. S. C.

The Camp Elwood Bredell

Silhouette **Elwood Bredell**

War Clifton L. Kling

Little Mother   Hatto Tappenbeck, A. S. C.

Irish Village Hatto Tappenbeck, A. S. C.

Desert Trail C. Curtis Fetters, A. S. C.

Disaster — Anthony Ugrin

Surf C. Curtis Fetters, A. S. C.

Out West Elmer Fryer

The Sentinel — Ned Van Buren, A. S. C.

Desert Study — Ned Van Buren, A. S. C.

Desert Study — Ned Van Buren, A. S. C.

Desert Study — Ned Van Buren, A. S. C.

Desert Study — Ned Van Buren, A S. C.

Desert Study — Ned Van Buren, A. S. C.

Desert Study **Ned Van Buren, A. S. C.**

Desert Study — Ned Van Buren, A. S. C.

THE STILL PICTURE'S PART IN MOTION PICTURES

Fred Archer, A. S. C.

THE still picture plays a very important part in the Motion Picture Industry, although, with the exception of a few who come into daily contact with it, its importance and its uses are but slightly known. To be sure, one says, almost immediately, "Why of course they are used to advertise the picture." This is correct—but there are equally important minor roles to be played by the still pictures before they are used for advertising purposes.

The main objectives of the still picture may be classified as follows: *Advertising the Production; Marketing the Production; Production reference work and Trick Photography.* It is in the latter three uses where the value of the still picture is but little known.

In the advertising field the still picture is used to illustrate and help plant the articles broadcast by the publicity department throughout the periodical world and it is used for lobby displays. In this field the necessity for good stills can be seen. The public of today is an apt pupil of the arts and their minds keep pace to the ever growing artistry of the world. A good still will attract and hold attention where many poor ones will receive but a passing glance.

In order to have these stills of the very best quality it is necessary to have good still men, men who understand composition and have a thorough knowledge of photography. No longer is the still man just a bulb squeezer, and many of the leading photographic pictorialists are being recruited into the picture industry to take care of these jobs.

In order to have a Motion Picture in a theatre for the public to view, it is necessary to sell that production to the theatre. There has long been a saying that "The Stills Sell the Movies." This is very true and many theatre managers, especially in these hurried times, have not time to view every picture produced in order to choose his program and the portfolio of stills carried by the salesman from the exchanges, telling quickly the story and quality of the movie is an essential need of the sales force. As this portfolio is to tell the story and shows the quality of the movie, it is very important that we have good still pictures to show to the theatre managers.

In order to have a good production for these salesmen to sell to these managers, it is necessary to make this good production. In production work the still picture is again invaluable. Even before a production starts there is a great deal of preliminary still photographic work to be done. Pictures gleaned from many sources, by the research department, showing costumes, buildings, properties and characters must be copied for the various allied artisans of the studio to refer to for their various needs.

A Publicity Still — Fred Archer, A. S. C.

Many times while filming a set it is necessary to photograph it with the still camera in order to redress it exactly the same, for retakes. Special make-ups must be photographed in order that they are the same day by day. The art department uses photographs of sets in order to use these sets for other pictures, planning from these stills the rebuilding or redecorating of these sets.

Cinematographers often have stills shot and rushed through the laboratory in order to get a confirmation of lighting, color values and other details before shooting a scene. It is very important in this instance that the still record just what the motion picture camera is to record. In these latter uses the stills save much time and are an invaluable asset to the production.

During the filming of one of the recent sea pictures it was necessary to film medium shots of a boat on the rocks being torn to pieces by the waves. This set was built in detail and hundreds of men were employed to work the various mechanisms used to truly portray this scene. A terrific expense went on hour by hour. The wreck was photographed in progression, each step requiring concentration and thought by all concerned. The daily rushes could not be seen until the next day. In order to keep the progression in their minds, the Director and Cinematographer had the Still man shoot each progression as each scene was filmed. These stills were printed and delivered on the set twenty minutes after being shot and were used to study out the subsequent progression. In this cast these stills were invaluable as a great deal of time and argument was saved, also a perfect progression could be figured step by step from concrete evidence of what had been shot.

Still pictures also play an important part in trick photography, helping the trick man with double exposures of clouds, scenery and many other helpful uses. In art title work still picture backgrounds are unexcelled. It is therefore very necessary that we have good stills from a production angle.

The Studio Portrait department, created a few years ago has grown to be quite a factor in the Publicity field and recently has broadened into a much larger field than heretofore. Besides the Portraits many different kinds of photographs are now made in the gallery, for instance there is the Pre-Production Art.

Before the filming of a picture starts and as soon as the players have received their finished costumes they are photographed against a plain or otherwise suitable background in scenes from the play. These are used for pre-production advertising and in the making of posters and bill board lay-outs. This enables the Publicity department to plant pictures in advance of the filming and as it takes about three months before the picture appears in the magazines on the news stand it allows the producer to tell the public in advance about the film which is soon to appear.

The artist in charge of the Portrait room creates ideas for magazine art and layouts to keep the magazines supplied with pictures which in turn keep the players and the title of the productions before the public.

Mr. Archer Shooting a Snow Still in the Studio

A Studio Snow Picture **Fred Archer, A. S. C.**

Mr. Archer at Work in His Studio

Fashion pictures of the players in the newest gowns and frocks are made for the magazines and Roto-sections of the papers. This fashion art is much sought after by the editors as the feminine readers of these sections are legion. These pictures also help to keep the players' names before the public and help to invite the public to our theatres.

Seasonal Art or art that fits into the season in which the then current magazine is published is also much sought after and is perhaps the hardest to get as it must be made months before it appears and Winter and Christmas art must be made about August, Fourth of July art in March and so on.

Imagine hunting for snow in California in August for Winter Sport pictures. The scene has to be built in the gallery and sweltering in the heat from the lights needed to keep the shadows off the walls and with the heat of the summer sunshine outside, the photographer feeling anything but wintery makes the winter pictures.

These settings built in the gallery have to be constantly changed. Thus one day the gallery has a snow scene, the next a Spring scene, an interior or some other background which may be needed for the idea in mind.

This branch of the art is new and is extending its sphere daily. The possibilities are unlimited and we who are engaged in this field of endeavor expect to help greatly with the exploitations of the pictures filmed by our various Studios and we hope that Still photography will gain the respected place in the industry which it justly deserves, for after all what would we do with our product if we couldn't sell it and the Still does Sell the Movie.

Meditation — Fred Archer, A. S. C.

MOTION PICTURE STUDIO LIGHTING WITH INCANDESCENT LAMPS

*R. E. Farnham**

THE present widespread use of incandescent lamps for motion picture photography began early in 1927 and closely followed the introduction of a successful ciné panchromatic film. Occasional use had been made of high wattage gas-filled lamps, particularly the photographic blue types for special effects and close-ups, prior to this, but the limitations of photographic apparatus and emulsions made the results in no way comparable to those of the present era.

Producers employ properties and costumes of a great variety of colors in the making of a picture, but much of the advantage that might be gained from an accurate representation of these colors in the picture was lost because of the limited sensitivity of the older photographic materials. The great popularity of panchromatic film has been due to its ability to register all colors correctly. However, this film is relatively less sensitive to yellow-red than blue-violet light, and to derive the full value of this emulsion, light sources possessing a much greater proportion of red-orange-yellow light than blue-violet are necessary.

The spectral characteristics of light of the high efficiency, gas-filled lamp meet the requirements of the panchromatic emulsion particularly well. Since panchromatic film forms the base of all color photographic processes, incandescent lamps are equally well suited for photography in colors.

Subsequent experience with incandescent lighting has shown that:

(1) Being absolutely quiet in their operation, incandescent units are especially desirable in sound picture production.

(2) Electrical labor for operating the lighting equipment has been reduced to a third or less of that previously required.

(3) The lighter weight of the equipment allows it to be handled more easily and quickly, making possible the photographing of more sets in a given period. Likewise, lighter and less expensive overhead supporting structures suffice.

(4) Because the light from the incandescent source can be so efficiently utilized and directed into areas where it is useful, one half or less electric energy is necessary than was heretofore required.

(5) The compactness of incandescent lamps and the variety of sizes and shapes available make possible many new and previously unobtainable lighting effects, including dimming.

Lighting Requirements

Lighting of motion picture sets involves intensity, distribution, and direction, as well as the color quality of the light. The color

**Engineering Dept., Edison Lamp Works, National Lamp Works, General Electric Company.*

quality is properly adjusted with the design efficiency of the lamp; thus there remains a need for effective control in directing the light that the various parts of the set may appear in their desired relative brightnesses and the highlights and shadows be at the command of the lighting director to enable him to obtain the precise effects called for by the action.

In a practical study of cinema studio lighting, it is convenient to classify the lighting as general and modeling. The purpose of the general lighting is to provide a ground work illumination which is fairly uniform throughout the set. It not only illuminates the areas that the modeling lights do not serve, but allows control of the shadow density. For the more usual cases, the general lighting does not create noticeable highlights or shadows; this is the function of the modeling lights. Of course, there are frequently instances where equipment normally used for general lighting can be employed to good advantage in creating modeling effects, as in the case of "close-ups."

Modeling by means of light is accomplished by the creation of highlights, shadows and contrasts, and equipment for this purpose should be capable of producing high intensities over small areas. For large areas at considerable distances, modeling equipments are often used for general illumination.

General Lighting

The intensities required for general lighting will vary with the nature of the set, the action, colors of the properties and the type of photography, that is, color or black and white.

A study of the general lighting requirements of a variety of sets and of other factors, such as lens speed and film characteristics, shows that the general lighting equipment should be capable of providing 200 to 500 foot-candles at distances of from 6 to 20 feet for black and white photography.

Broadside Units

Ordinarily, the camera is aimed nearly horizontally and hence the illumination on vertical surfaces is most important. For the smaller sets, much of the action usually occurs over areas from 6 to 12 feet deep and the required light can be provided best by lighting equipment placed either side of the camera.

These broadside lighting units ("broadsides") should be capable of providing relatively uniform illumination through horizontal and vertical angles of approximately 60 degrees, and the horizontal angle of cut-off should not be greater than 90 degrees in order to keep down the illumination on the side walls of the set and the spill light from striking the camera.

It is fortunate that both the horizontal and vertical angles of uniform light spread are approximately the same (60 degrees), as this permits a symmetrical reflector with resultant high utilization of the light.

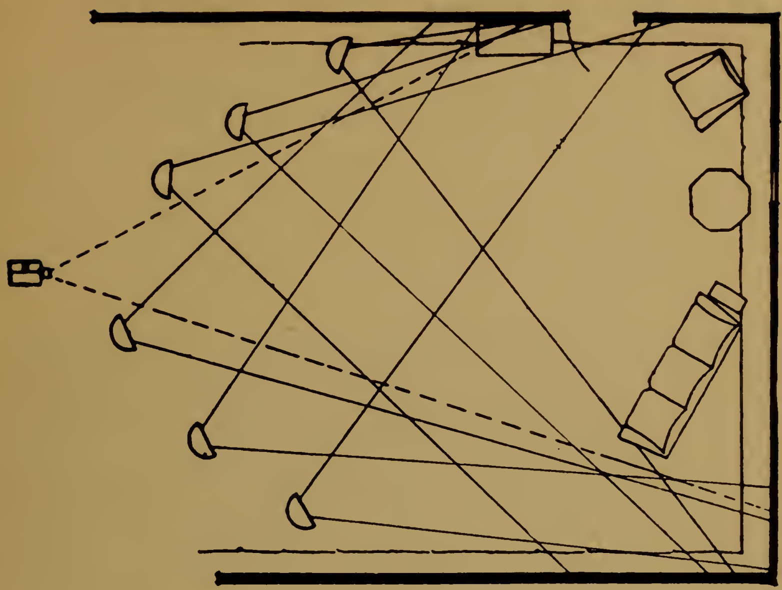


Fig. 1
For general lighting, reflectors giving a fairly uniform horizontal light distribution within an angle of 60 degrees, give good coverage with minimum waste of light.

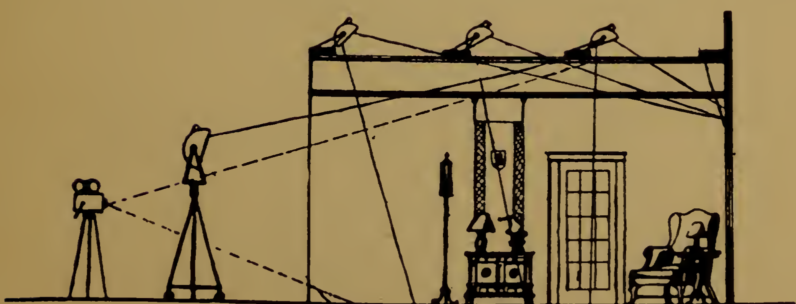


Fig. 2.
Sixty degrees vertical spread meets the requirements of both overhead and floor broadsides.

There are three satisfactory materials from which broadside lighting reflectors can be made—mirrored glass, etched aluminum, and chromium-plated metal. Mirrored glass has the advantages of high reflection efficiency and negligible deterioration, provided the reflector is of adequate size for the wattage of the lamp used. On the other

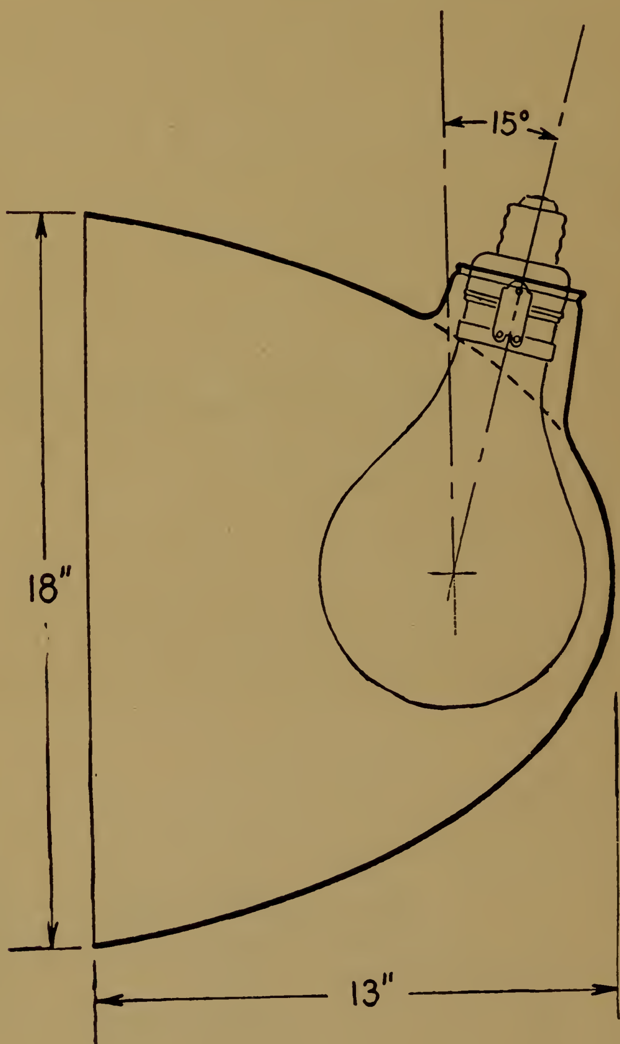


Fig. 3.
The general contour of a reflector designed to give both uniform horizontal and vertical light distribution through an angle of 60 degrees. The reflecting surface should possess semi-specular reflecting characteristics. Applicable to both overhead and floor broadsides depending on the type of mounting.

hand, it is heavy, liable to breakage, and expensive. Etched aluminum is nearly as efficient as glass, light in weight, and relatively inexpensive. However, the roughened reflecting surface, incidental to the etching or production of the matte finish, accumulates dirt easily and the aluminum reflectors must be cleaned rather frequently to maintain their good efficiency. The reflecting efficiency of chromium is about three-fourths that of silvered glass; however, it maintains this efficiency over long periods of time. Chromium-plated reflectors are relatively light in weight and of course are not subject to breakage. They are satisfactory for studio lighting service. Both the silvered glass and the chromium plated reflectors possess specular reflecting

Fig. 4.
A "Dome" general lighting unit, frequently necessary where the scene is shot simultaneously from several directions

characteristics; therefore, the surface should be configurated or rippled to remove striations and improve the uniformity of the illumination.

Overhead Units (Scoops)

For the deeper sets, overhead units are needed to direct light to the rear areas that cannot be illuminated satisfactorily by the broadsides. If the light output of the latter were increased sufficiently to provide ample light in the rear, the illumination intensities nearer the front would be undesirably high, so that it would be difficult to obtain satisfactory contrasts with the modeling lighting.

Since the overhead units are placed across the set similarly to the floor broadsides, we find here also that the 60-degree horizontal and vertical distributions adequately meet the requirements, thus permitting the use of a symmetrical reflector similar in contour to the floor broadside. The same reflector, but with a suitable mounting for overhead work, serves admirably for lighting from above.

Modeling Lighting

With only general lighting, the illumination of a motion picture set would be flat and the various actors would be equally conspicuous from a brightness standpoint, owing to the lack of highlights and contrasts. To model the features properly, to give emphasis to certain actors, and to create an appearance of depth, additional lighting is employed to give much higher intensities over limited areas. This we designate as modeling lighting. To produce distinct highlights, intensities ranging from two to four times that of the general illumination are required, although ratios considerably higher are sometimes employed. Therefore, the modeling units must be capable of producing intensities of from 200 to 1,500 foot-candles, and with beam divergencies of from about 7 degrees to 30 degrees.

Two types of modeling units are commonly used—the reflector projector, and lens spotlamp. The (parabolic) silvered glass mirror projector utilizes approximately four times as much light from the lamp as the lens spot and is therefore much more widely used. The lens projector is somewhat more compact and finds application in "close-up" work.

Table 1—Reflector type Modeling Units

Diameter of Silvered Glass Mirror (*Inches*)	*Focal Length* (*Inches*)	*Distance from lamp to Actors* (*Feet*)	*MAZDA Lamp*
18-20	6-8	12-20	2000-watt G-48 bulb
24	10	20-50	5000-watt G-64 bulb
36	15	50 and greater	10000-watt G-80 bulb

Silvered glass mirrors permit much more accurate control of the light and are most efficient. Softening of the light and flooding can be satisfactorily accomplished by diffusing doors.

When using the reflector projectors at the wider beam spreads, 20 to 30 degrees, the illuminated area tends to darken at the center due to the light rays forming the center of the beam moving outward at a greater rate than the outer rays, as the light source is moved away from the mirror focal point. A satisfactory method of improving the spot uniformity and still retaining a well defined spot is to employ a cover door of Solite wire glass.

Special Lighting Effects

Because of their compactness and convenience as well as the many sizes and shapes available, MAZDA Lamps are being used to create many lighting effects in which the lamps appear in the picture as contrasted to the higher wattage types employed as photographic light sources.

The customary lamps used for wall brackets and table lamps do not register through the high intensities and it has been necessary to

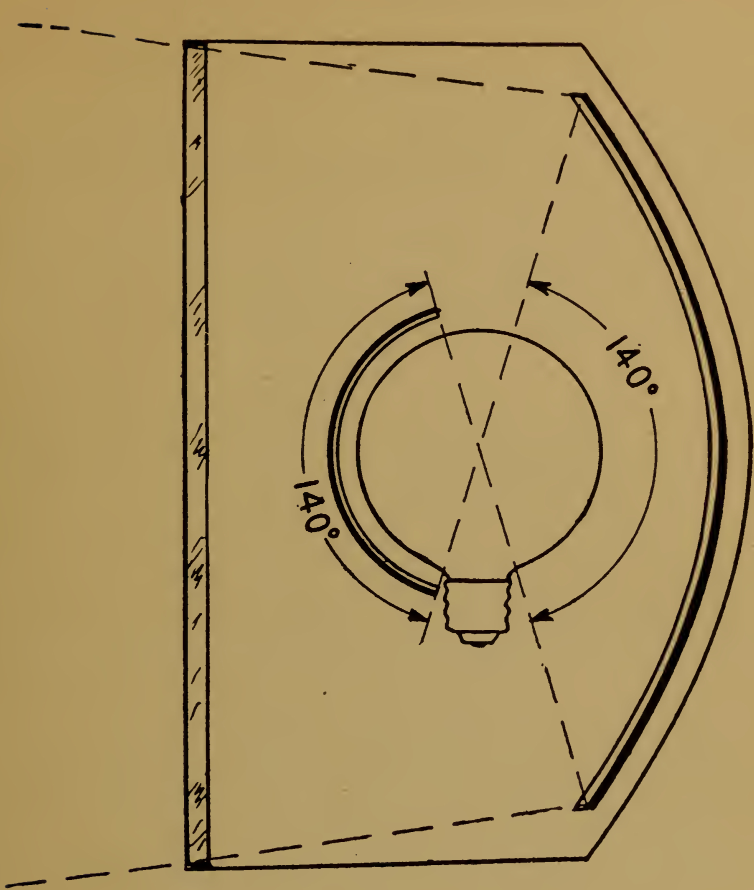


Fig. 5.
A schematic representation of a modeling lighting unit employing a mirrored glass parabolic reflector.

"spot" them with a beam projector to give them a lighted appearance. The result is seldom satisfactory. By the use of either the 200 or 500 watt tubular bulb projector lamps, which are approximately the same size as the lower wattage lamps normally used, sufficient brightness is obtained to give them a lighted appearance.

Both the small 10-watt S-11 bulb lamps in a variety of colors, and the larger sign lamps, have been employed in large and miniature signs. The extremely small flashlight lamps simulate fireflies. Bare 1000-watt lamps shining through muslin give an appearance and twinkle of stars. MAZDA lamps can be operated under water, provided, of course, they are turned on and off while in the water to prevent sudden chilling of the bulb, and if the water is agitated, the ripples become luminous. The electrical connections should be waterproofed.

Table 2 Mazda Lamps for Motion Picture Photography

Watts	Volts	Bulb shape	Bulb diam. inches	Bulb designation	Light center length	Filament Construction	Overall length construction	Base	Burning Position	Service
1000	115	pear	6–½	PS 52	9–½	C–7	13–⅛	Mogul	any	General
1000	115	tubular	2–½	T–20	4–¾	C–13A	9–½	Mogul	base down	General
1500	115	pear	6–½	PS 52	9–½	C–7	13–⅛	Mogul	any	General
2000	115	spherical	6	G–48	5–¼	C–13	8–⅝	*Mogul	base down	Modeling
5000	115	spherical	8	G–64	9	C–13	15–½	Prong	base down	Modeling
10000	115	spherical	10	G–80	12	C–13	20	Prong	base down	Modeling
		A few suggested types for special effects								
	2.3	spherical	$\frac{7}{16}$	G–3–½			$\frac{15}{16}$	min. screw	any	flashlight
10	115	straight side	1–⅜	S–11	1–½	C–7A	2–$\frac{5}{16}$	inter. screw	any	sign
25	115	pear	2–⅜	A–19	2–½	C–7A	3–$\frac{15}{16}$	medium	any	sign-inside frost daylight
200	115	tubular	1–¼	T–10	3	C–13	5–½	*med. screw	base down	Wall brackets (projection)
250	20	tubular	1–¼	T–10	3	C–13	5–½	*med. screw	base down	where supply must be from storage
500	115	tubular	2–½	T–20	3	C–13	5–½	*Med. screw	base down	table lamp (projection)

* Available with prefocus base

Low voltage types that can be operated from a storage battery are available making it possible to mount lamps on a moving vehicle.

MAZDA Lamps

Lamps for general lighting service have semi-concentrated filaments as compared to the highly concentrated sources of the modeling service lamps. They can be operated in almost any position, although their best performance is obtained when burned base-up.

The modeling lighting lamps are characterized by concentrated light sources. The monoplane filament construction possesses a number of advantages over other types, particularly freedom from color and greater uniformity in the illuminated field.

Equipment Maintenance

Dust or dirt on lamps and reflector surfaces greatly reduces their efficiency. Observation of many equipments employed for some time in studio service has shown an accumulation of dust and finger marks sufficient to reduce the light output 50 per cent. The lamps and lighting equipment should be cleaned periodically and reflecting surfaces kept in good condition. The 5 and 10 kilowatt lamps, which contain a scouring powder within the bulb to remove tungsten deposit, should be regularly cleaned by whirling the lamp. The cost of this maintenance is really an investment capable of big dividends, and its importance cannot be over-emphasized.

Correct Voltage Operation

Mention has previously been made of the excellent way in which the light spectral characteristics of the light of high wattage MAZDA lamps fits the color sensitivity of panchromatic film to produce correct rendering of colored properties. Operation of incandescent lamps at voltages below that marked on the lamp results in a very material reduction in the volume of light given out by the lamp, particularly the blue-violet components. Additional lamps and equipments are then needed and the reds, oranges and yellows are over-corrected. Likewise operation at voltages above normal tends towards over-emphasis of blues and violets. Cinematographers, interested in obtaining the highest quality in their work, should make certain that the lamps are operated at their label voltages. Voltage readings at the substation are insufficient; the supply voltage should be checked at the nearest centers of distribution.

Jackson J. Rose, A. S. C.

COLOR RENDITION

A Series of Practical Tests of the Monochromatic Rendition of Color with Commercial Motion Picture Negative Film.

Jackson J. Rose, A. S. C.

THE past year has seen tremendous advances in the popularity of natural-color cinematography for the production of dramatic feature pictures and short subjects. Nevertheless the motion picture industry as a whole continues to operate on a black-and-white basis. Yet even so, the question of color and its rendition is of vital importance to cinematographers, for black-and-white pictures are nothing more nor less than representations of the form and color of a scene in monochrome. Therefore it is of the utmost importance that cinematographers and art-directors and others interested, know exactly how every color and shade will photograph under every condition of lighting and filtering, and upon every available make of film.

The long years of experience behind most cinematographers and art-directors is sufficient to give them a fairly accurate judgment of such things in most cases, but there are times when even the most extensive experiment must be at a loss to find the right answer to such problems. Furthermore, the opinions of experienced cameramen as to the photographic value of certain materials may often be diametrically opposed. An instance of this occurred in the writer's experience some time ago: in the course of his work in photographing a picture at one of the larger studios he had to photograph a set whose background was largely composed of green cloth. According to his judgment this background should have photographed in a very *light* tone, while according to the judgment of one of his colleagues—an equally experienced cinematographer—the set should have photographed in a very *dark* tone. They both were careful in giving a decision, in this case both the Pan glass viewing filter as well as the Blue glass were brought into play. In the projection room the next day the film was viewed, and it was found that neither man was right, and that the green of the set photographed as a *dark grey*, midway between the two values predicted.

In itself, this incident had no practical value; but it very clearly showed the writer that something was wrong. Here were two experienced, veteran cinematographers, whose judgments of the photographic value of a certain color were diametrically opposed, and who were both proven to be wrong by actual practice. Furthermore, every practicing cinematographer can easily cite a dozen similar instances from his personal experience. This pointed to an alarming state of affairs, for the keynote of the cinematographer's work is his exact knowledge of the photographic value of every object and color he is to photograph before money is needlessly expended on construction and photography. He is almost the only man in a studio who cannot say, "This *ought* to photograph thus and so." He must know, *positively*, how it will appear.

Illustrating the method of photographing the test sheets

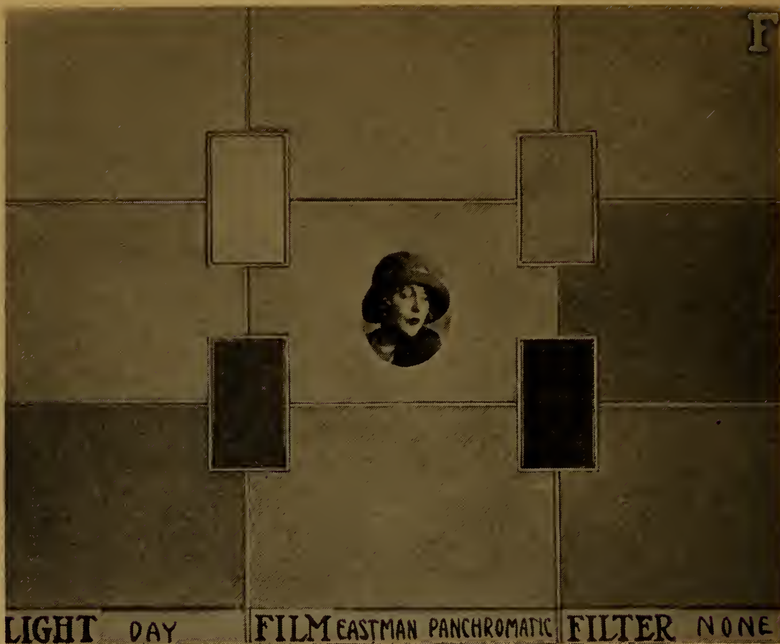
The five loose-leaf albums containing the original color-charts and the complete results of the tests.

Of course there are certain aids in determining the photographic values of such materials by inspection through the various monotone viewing-filters available; but the writer's personal experience with such filters is that none is uniformly accurate with all colors and under all light conditions; in fact, no such filter will give an accurate reading for any single sensitive material under nearly all the conditions met with in the course of general studio work. For instance, the so-called "Pan glass" is reasonably accurate inasmuch as it will show *about* what one will get on Panchromatic film *with a K-2 filter;* but with either a heavier or lighter filter, or with none at all used, this glass is entirely incorrect. The same may be said of the so-called Blue glass or C monotone filter. It is useless to use such a filter when photographing with Mazda light or Panchromatic film. It may, however, give one a fair idea of the color rendition when Arc or Hard light or even Cooper-Hewitt light is used, and even in daylight when one is using Orthochromatic film, but for other uses this filter is of little value. Therefore, it is this writer's suggestion that if a single pair of accurate, neutral-colored viewing-filters (one for Orthochromatic film, and one for Panchromatic) could be devised, it would be a great boon to the cinematographic profession. To be absolutely accurate such a filter would of course have to be made in several different densities to take care of the use of various kinds of filters as well as both Orthochromatic and Panchromatic emulsions.

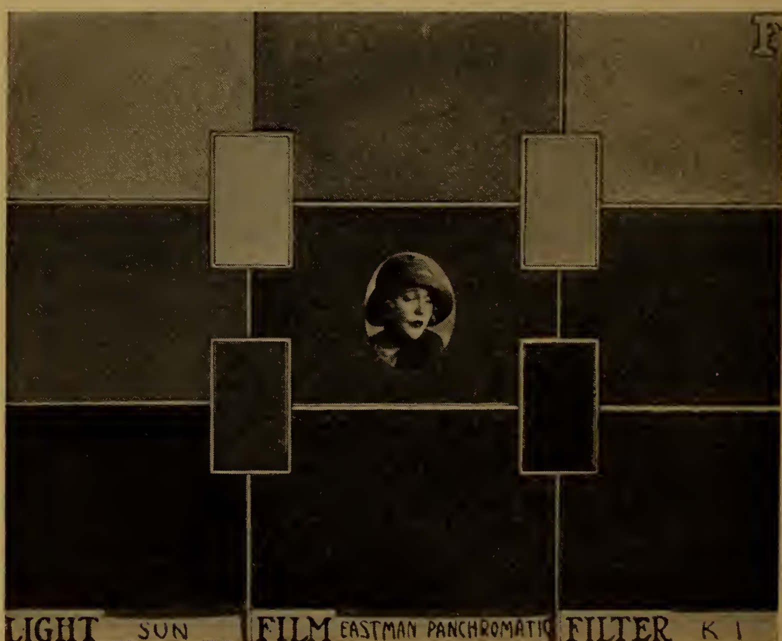
In view of the existence of the condition just outlined, it appeared to this writer that a systematic series of tests of the various sensitive materials commonly used in the studios, and covering a wide range of colored materials and textures, made with absolute uniformity, under the light and filter conditions most commonly met with in studio practice, would furnish a far more nearly scientific basis from which to judge such photographic values than experience, filters, or any previous tests with which he was acquainted. Accordingly, he set himself to the task of devising and executing such a series of tests. The first problem was to collect a comprehensive amount of colored materials in every shade and tone possible and then to segregate the different shades and tones of each individual color, eliminating those that were not necessary.

The second problem was that of arranging the color-specimens to be photographed in a way that permitted several different shades and tones of the same color to be easily compared. This was done by arranging the color-charts with nine squares of different shades of each color to the sheet. Then, to form a basis for more rigid comparison, each sheet was also provided with identical monochromatic squares of white, light grey, dark grey, and black.

But these test films must all be exposed and printed so as to preserve the same relative factor of density for the entire series, or the tests would be valueless. To this end identical photographs were placed at the centre of each of the test-sheets, and exposure and printing were keyed by these. In the final, enlarged prints these photographs all showed the same density, the relative densities of the dif-



One of the tests: Color-sheet F, embracing the blues, photographed on Eastman Panchromatic film, by daylight, with no filter.



One of the tests: Color-sheet F, embracing the blues, photographed on Eastman Panchromatic film, by sunlight, with K 1 filter.

Color Chart " F " . . . the Monochromatic Rendition of this chart by Eastman "Type Two" Panchromatic film is shown on the opposite page.

ferent color-squares would be uniform, and the tests therefore accurate.

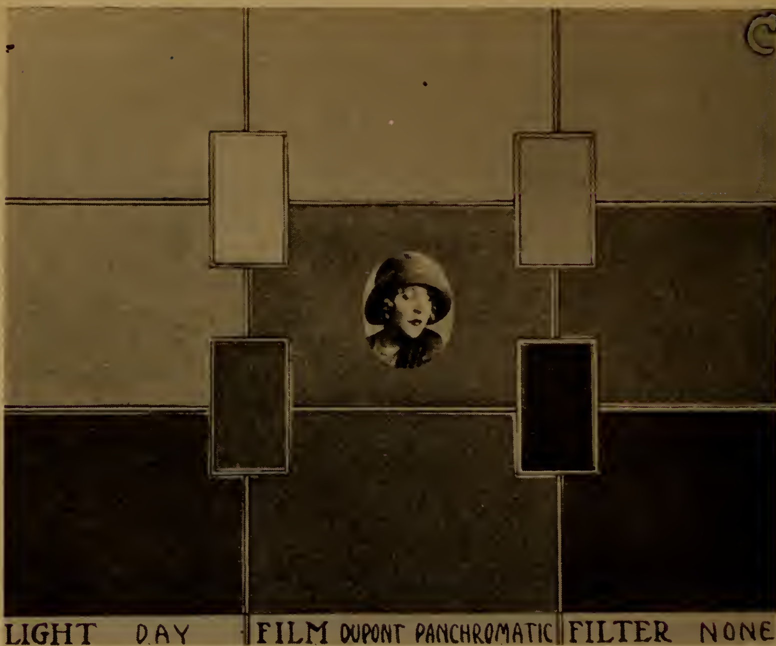
Then came the problem of the manner of photographing these tests. Obviously, it would have been considerably easier to have photographed them with the conventional 8x10 still camera; but this would have been no true test, for, contrary to the general opinion, the writer found that the emulsions coated on photographic and cinematographic films by the various manufacturers are entirely different in many characteristics. Furthermore, this would have given no measurement to the grain of the several cinematographic emulsions—a feature which is also of great importance to the cinematographer. Therefore, these tests were made on standard motion picture negative film, in a standard motion picture camera; in order that the exposures might be absolutely even, a motor was used, and a definitely fixed footage—fifteen feet—was exposed in each case. A total of about 10,000 feet of film was exposed in the course of these tests.

The negative exposed was treated in the identical manner in which it would have been treated if it had been a part of ordinary, commercial production. It was developed in a well-known commercial laboratory, by machine methods, and in the solutions regularly employed by that laboratory. In fact every step in the making of these tests was as close to normal production conditions as was humanly possible.

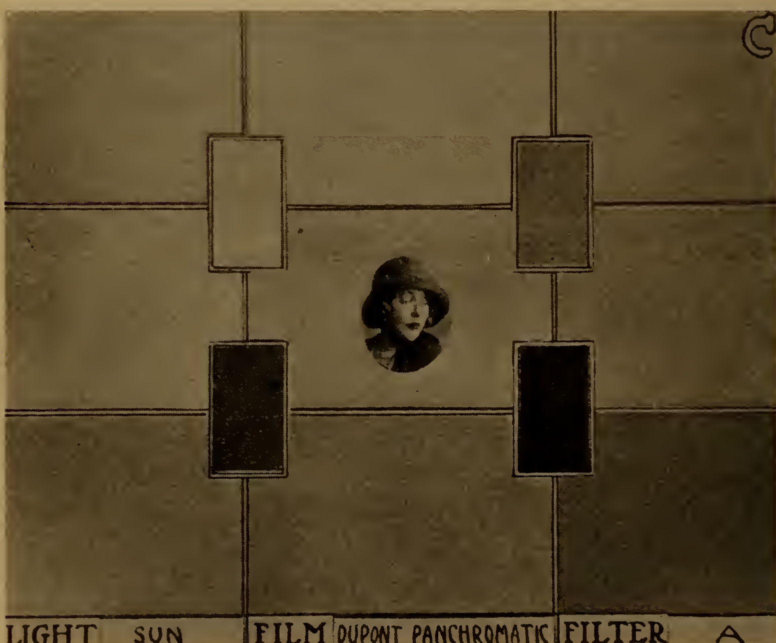
A single frame of each test strip was chosen at random and enlarged to 8x10 inches, being printed on glossy stock, and, as said before, to a uniform relative density. These prints were then mounted on a muslin backing, and fitted with a hinge, and the tests of each make of film collected in a separate, loose-leaf album, as were the original color-charts. It is well to note that the record of each film, light and filter was photographed with each color sheet making a single, permanent record. Together, these five books comprise as complete a set of reference-charts as the author has thus far been privileged to inspect, and it is with what he hopes is pardonable pride that he presents them to the cinematographic profession.

The color-chart sheets which were photographed in this test number nineteen; each sheet contains squares of nine different shades or colors, making a total of one hundred and seventy-one different colors and shades tested; these have been photographed on each of the four makes of film most used in America production, viz., Eastman *Type Two* Panchromatic, DuPont Panchromatic, Agfa Panchromatic, and Agfa Super-Speed (Orthochromatic). Nine different light and filter conditions were used on each test. It is well to mention here that the same lens, a four-inch Pan Astro was used in all these tests and at its full opening of *f:* 2.3. The shutter, of course, was manipulated to compensate the variations of light and filters used.

The colors on the test charts are arranged as follows, nine different shades being grouped on each sheet:



One of the tests: Color-sheet C, embracing the light reds, photographed on DuPont Panchromatic film, by daylight, with no filter.



One of the tests: Color-sheet C, embracing the light reds, photographed on DuPont Panchromatic film, by sunlight, with the A filter. Compare the rendition of this with that of the same subject photographed without a filter.

Color Chart " C " . . . the Monochromatic Rendition of this chart by DuPont Panchromatic film is shown on the opposite page

The Eastman *Type Two* Panchromatic emulsion showed itself particularly satisfactory in the rendition of the blues, as with it almost every shade of blue was rendered accurately and pleasingly. This particularly adapts this film for use when making night-effect scenes by daylight, with the A or F filters. It is also well to notice the vast difference caused by the use of the ordinary yellow filters with this film. The illustration shows this very clearly, Chart F being the one which comprises the blues, and the illustrations showing how it photographed with and without the use of a K 1 filter.

The DuPont Panchromatic emulsion proved itself particularly superior in its red-sensitivity, being, if anything, somewhat more sensitive to this region of the spectrum than any other film tested. This characteristic makes it particularly desirable when photographing people with a high coloring, when they use little or no make-up. This characteristic also adapts it to fire-scenes, and to night-shots where artificial illumination—particularly incandescent—is used. The illustrations show the results of photographing color-chart C, which embraces the lighter reds, with this film. Notice the vast difference between the tests made with and without filters. It is worthy of mention at this time that the general color sensitivity of this film was very satisfactory and its speed ratio was highly pleasing. This film showed slightly softer results in the darker colors.

The Agfa Panchromatic proved itself particularly sensitive to the yellows and oranges, which makes it especially suitable for photographing sunrise and sunset effects, and gives it excellent characteristics for general use with incandescent lighting. The high yellow sensitivity also makes the use of the K series of filters particularly beneficial, as the illustrations show. Although in most cases this film showed much more contrast than either the Eastman or Du Pont, its speed was also slightly slower, which is desirable for certain effects.

In all the tests of the Agfa Super-Speed (which of course is an Orthochromatic emulsion) many interesting results were noted and it is well to mention that while this film lacks the color sensitivity shown in the Panchromatic emulsions, it is very desirable on account of its high speed and can be used especially when light conditions are very poor. In a series of tests made in very subdued light, this film showed most favorable results although its color rendition could not be as satisfactory as that of Panchromatic film. In illustration number 3 you will notice the results of this film upon a yellow color sheet.

These few remarks are all which the space allows to be made about the definite results of these tests. In closing, however, the writer wants to reiterate that these tests were made, not only as a means of securing practical information which he found vital to his personal work, but as a means of obtaining and codifying a vast mass of data of which his experience showed him the Cinematographic Profession as a whole stood in urgent need.

Dawn

MOTION PICTURES IN NATURAL COLORS

Hal Hall and William Stull, A.S.C.

THE past year has witnessed phenomenal changes and developments in the motion picture industry. The advent of sound set the industry upon its toes, as it were, and progress was the watchword of everyone. Perhaps no greater progress was made during this year than that in the field of color cinematography. From what might almost be termed a glorious experiment, color leaped into prominence and became almost over-night one of the biggest factors in the production of motion pictures. The world became color conscious and color systems began springing up in all quarters.

Technicolor, which has been in the van for years, naturally has led the color parade, for it had at its command vast resources and laboratories; and in the past it was Technicolor which was mainly used in the color sequences which dotted pictures here and there. However, other processes have come rapidly during the past year, with Multicolor stepping forward as probably the most outstanding of the new processes. Others springing into prominence included Harris Color, Photocolor, a special color process of the Eastman Kodak Company which is now being called Fox Color, but which was formerly known as Kodachrome, and for the 16-millimeter film came Kodacolor and for a time Vitacolor. In addition to these there are many other processes in the experimental laboratories.

As color in motion pictures is apparently here to stay it might be well to go back at this point and see just what color is and what the developments have been. Naturally, the starting point of a discussion of any subject is a reasonably clear understanding of what is being discussed.

Color really is the mental result of the physical action of different light waves on our optic nerves; but what is it that makes these results differ? In the first place, we have not gone back far enough to reach the real source of color. We must recall that color is a manifestation of light—so our real beginning must be light.

Light, we know, comes from all incandescent or burning bodies, and is reflected by all others. Now, light itself is an electromagnetic wave-motion in the ether. These light-waves are much the same as radio waves, but they are broadcast on a shorter wave-length and at a tremendously higher frequency. Instead of measuring their wave-length in metres, we measure it in ten-thousandths of a millimetre, and the frequency in hundreds of trillions per second. No wonder we can't tune it in on our radios! These waves cover a rather considerable range of frequencies and wave-lengths, and the differences of these are responsible for the effects we call color.

Pure white light, such as comes from the sun, is a complete and perfect mixture of all these frequencies, but that which is reflected from the different objects around us is minus various frequencies, which have been absorbed by the object. Thus, a red rose reflects those frequencies which give us the sensation of *red*, and absorbs all the others. Similarly, its green leaves reflect the *green* vibrations, and absorb the others. Thus it is with all colors: *black*, of course, means an almost complete absorption of all frequencies, while its opposite, *white*, is a complete reflection of all frequencies. *Gray* is merely an imperfect white; uniformly absorbed in all frequencies, cutting down the chromatic brilliance of the object, though not necessarily lessening its *visual* brilliance.

Furthermore, scientists have found that white light may be reduced to three *primary colors*, which can be combined to form all the others. These three are *red, blue, and green:* they correspond to the three different units of our optic nervous system. If all three units are excited equally, we get the effect of *white;* if they are affected unequally, we get the effect of color corresponding to that mixture of these primary colors. Thus it will be apparent that if we can make three photographs of an object, each one so filtered as to just record the proportion of the frequencies of the total reflected light in the picture that one of these three nerve-units would get, and then in some way combine the three, each having been colored its appropriate hue, we should get an exact reproduction of the object in its original color. This is the idea behind all color photography. In actual practice it has been found possible to use only two color-images—those of the red and green—and still get a fairly good color-picture. Of course the loss of the blue means also the loss of absolute fidelity in the color representation; for instance, white is actually rendered as a pale yellow, which we see as white; but it also means such a degree of mechanical simplification that the sacrifice of perfect accuracy seems justified. This is especially so in kinematography, where the mechanical difficulties are already so numerous.

Two Kinds of Color Process

But, whether two or three colors are used is not the chief difference between the various color processes. Regardless of the number of colors used, all color-photographic processes range themselves into two groups: ADDITIVE and SUBTRACTIVE processes. *Every system of color photography thus far devised or suggested falls under one of these two heads.* Some combine the two. Briefly, in an additive process, the film itself carries no actual color: the color-values are latent, and are revealed by appropriate filters placed or moved between the film and the screen. In a subtractive process, the picture is in itself a complete, self-contained, color-record, needing no filters or other special equipment for projection. Each of these systems has its individual advantages and disadvantages. For instance, the additive processes' films are in no way special, and may thus be handled in the ordinary manner: but at the same time, special apparatus is required for both taking and showing. On the other hand, though the subtractive processes require special cameras and special processing, their films may be run on any projector—a great commercial advantage.

Now, further than this, the additive processes divide into two categories: those whose separate color images are made and shown successively, depending upon persistence of vision to form the combined color-pictures; and those whose separate color-images are taken simultaneously, and superimposed by projection, giving a single, complete color-picture on the screen. Obviously, the first of these two is by far the easier to handle, but it has the disadvantage of creating a considerable strain on the viewers' eyes—generally causing severe frontal headaches from the optical effort of combining the several successive partial images into one complete colored one. In addition, these successive processes have another disadvantage: they often show a colored fringe around the edges of a moving object. This is natural, for, in the simple case of, say, a hand in motion, it could hardly be expected that the red image, having been taken a fraction of a second after the green one, would show that hand in exactly the same position. Obviously, if the two were superimposed one on the other, they would be a trifle out of register, and leave a tiny clear space around the edges of the hand. On the screen, then, one of those clear spaces will be red, and the other green, giving to the eye the effect of a flickering red and green fringe around the hand during its movement. On the other hand, simultaneous images, whether projected from separate films, as in some systems, or by a multiple lens arrangement, as in others, naturally require a lot of extra apparatus, which is a serious drawback, commercially. Incidentally, if separate films are used, the problems of maintaining exact register assumes unpleasant proportions.

All in all, the problems of color cinematography are so numerous that it is a great credit to the many individual experimenters that the matter has been brought to its present successful stage, where films in color are not only practical for professional use, but available for amateurs as well. The steps leading up to this present condition are many, and interesting, and even a brief review of the outstanding ones may prove helpful to the users of today's perfected color systems.

Early Efforts

It is not generally known, but the first film made for screen projection—Jenkins', in 1895—was in colors, having been hand-tinted by a Mr. Boyce. A year later, Robert Paul, an English experimenter, also tried hand-coloring. Anyone who has tried to color still pictures knows what a task it is to do a really perfect job on one single picture: consider, then, the difficulty of coloring the tiny images on a movie film; and then — think of the infinite numbers of these images in even a few feet of film! Paul finally achieved a colored version of his seven-reel production of "The Miracle", but the real miracle of it was the job of hand-coloring its 112,000 frames. After fighting his way through to success in this matter, Paul decided that the only thing to do was either to abandon colored films entirely, or put the coloring on a mechanical footing. He chose the latter, and finally evolved a system of mechanically stenciling the colors through hand-made masks. That this system is effective is evident by the fact that there survive today two improved stencil systems, the famous and beautiful Pathecolor, and the less-known but equally successful Handschiegl Process used for special effects by many of the American studios. Probably the outstanding example of this process in most memories is its application to the torches of the soldiers in Marion Davies' hit of a few years ago, "When Knighthood Was in Flower".

However, two years after these first experiments in synthetic coloration, another Englishman, Friese-Greene, developed what is probably the first process of true natural-color cinematography. This was a complicated three-color additive process, using orange-red, green, and violet, and combining the successive and superposed schemes. The pictures were taken on two separate films by an ingenious twin-lens camera, and projected by a similar projector; the color-cycles were echeloned, so that the pictures partly overlapped. That is, the left-hand projector would be projecting, say, a green image, while the right-hand one was projecting its blue one. Then the left-hand image would shift to red, after which the other would change to green, and so on. To make matters more interesting, the color-shutter was not a revolving disc, nor pair of discs, but a tinted film-band superimposed on the film! All told, it must have been a proposition capable of giving even the best operator nightmares. Clearly, it couldn't be much of a commercial proposition; and contemporary opinion doesn't indicate it to have been a vast success artistically, either, for the color-rendering is said to have been seldom good, and often entirely imaginary, while the pictures were not only fuzzy, but most unsteady. Apparently there was still almost undiminished room for improvement.

Kinemacolor

The next major development was the famous Kinemacolor process. No one who ever saw them will be likely to forget the beautiful and spectacular scenes made by this process of the ceremonies attending the funeral of the late King Edward of England, and the coronation of the present king, culminating in the unforgettable scenes of his visit to India, and the impressively beautiful Durbar. Kinemacolor was a two-color, additive process pure and simple, and exhibited all the advantages and disadvantages of that type. The films were made and projected at the rate of 32 frames per second—twice the standard. There was only one film used in the camera, but the shutter used was double, making one revolution for every two frames, and exposing these frames alternately through a green filter and a red-orange one. The film used was the ordinary stock, as no other was available in those days, but specially panchromatized by the Kinemacolor firm. It was processed in quite the ordinary way, giving a conventional black-and-white print, which bore only latent color-values, which were revealed by a revolving red and green shutter on the projector. This shutter was made adjustable, so that the correct color values could be obtained with any machine. The red gelatine in it was fixed, but the green one was not: it was double, having one fixed segment and one moveable one, which partly overlapped. By adjusting the amount of this overlapping in the green sector, all variations in the colors of the light-source could easily be compensated for. All that was necessary was to adjust the shutter so that when the machine ran, empty, at speed, the screen seemed perfectly white. Another interesting detail of Kinemacolor practice was that the titles were made only on the green frames, as a safeguard to perfect color-framing, while there was also an identifying spot printed at the side of each green frame. Kinemacolor's results were very beautiful—at best, quite equal to anything now current—but the pictures were troubled with fringing, and also gave rise to considerable eye-strain. As they also required special projection equipment, due to the special shutters and the high speed, the process was not long-lived commercially.

Gaumont's Process

About the same time, M. Leon Gaumont, the famous French cinema engineer, devised a very excellent system using three color-images, made and projected together through an ingenious triple lens system. The three pictures were one above the other, and occupied the same length of film as two normal frames. The resultant picture was, according to Dr. Mees of the Eastman Laboratories, "—admirable, all colors being perfectly rendered and the quality—in every way first class." However, its unfortunate need for special apparatus limited its commercial usefulness.

Eastman's Kodachrome

Clearly, to be truly a commercial success a process would have to be applicable, at least in projection, to all existing machines. This points to a subtractive process. One of the earliest of these, and a typical one, is Eastman's "Kodachrome", which was developed by J. G. Capstaff. This, again referring to Dr. Mees' monograph on the subject, was taken with a special camera which made two successive pictures—the red and green images—one below the other. This was printed through a special projection-printer, on a special stock, which had a sensitive emulsion on either side; the two images were printed exactly opposite each other, and in perfect register. The two sides of the film were dyed appropriately—one red, the other, green—and the film was ready to run. Being in itself a complete color-record, it could be used in any standard projector, with no special adjustment at all. The "Kodachrome" process is quite successful, though it has not been so extensively exploited as some others, and it is still in use today.

Prizma

The next to capture the spotlight was "Prizma," a beautiful process which enjoyed a most checkered career, finally failing through no fault of its own. Prizma began life in 1917, as a pure four-color additive process, using red-orange; blue-green; yellow, and blue-violet. It gave beautiful results, but was hardly more than a laboratory experiment yet. The next development was in reducing it to a simple two-color process, and eliminating the filters by putting them on the film: this was done by dyeing the alternate frames their appropriate color. In this form it began to show signs of being a commercial product. Finally it blossomed into real practicability by being adapted to give a subtractive print, very much after the fashion of Kodachrome. For several years after this development, which occurred about 1921, Prizma flourished as the proverbial green bay-tree. Many of the major producers used it for special scenes and inserts, while several features were made entirely in Prizma. Mae Murray and her producers were Prizma enthusiasts, while D. W. Griffith, Hugo Ballin and the Famous Players Company also made use of it. Abroad, an English company made at least two features in Prizma, under the direction of Commodore Blackton. All in all, Prizma seemed headed straight for success in a big way. Just at that time, however, the film industry was beginning its last great migration to the Pacific Coast. Prizma did not choose to run, so it stayed and languished in its inaccessible laboratory in Jersey City. Had it joined the rest of the industry in its Westward trek, there is no doubt that it would be with us today.

Technicolor

About the time Prizma began its decline, a new face was pushed over the cinematic horizon. A group of engineers from Boston had evolved a process which they called Technicolor, and with which they proposed to brighten up the movies. When Technicolor took its first bow, it was a two-color twin-lens proposition, which gave fine results in the laboratory, but not in the studio. This was soon abandoned for a subtractive process, which achieved considerable success. The negative was made in a special camera which made the two color-images through a single lens, at one exposure, by means of prisms. The two sets of negative-frames were then printed onto two separate films, which were appropriately dyed, and then cemented back-to-back, in perfect register. This gave a very satisfactory print indeed, and one which could be run in any theatre. However, it had two slight drawbacks: it was rather denser than the ordinary print, requiring a more powerful projection-light, and, as the film was thicker, the focus of the projector had to be altered between black-and-white and color sequences. Still, the process caught on commercially, and became quite a success.

Of late, however, Technicolor has made a number of improvements which have placed it at the forefront of professional color processes. The double film has been entirely done away with, while production has been so simplified that the cost has been lowered very considerably, and the volume tremendously increased. In the new process, the actual taking is practically the same, but the printing is entirely different. Two separate prints are made, one of all the red images, and one of the green ones. These are so treated that the image is in relief, in the gelatine itself. Then they are inked, just as printing type is, and brought in contact with a strip of clear film, carrying only a gelatine coating. The two images are printed onto this film, one over the other, exactly as colored pictures are printed for a magazine. This is known as *Imbibition printing,* and has long been a recognized method of producing still color-photographs, but has not been successfully applied to movies before on account of the way the colors spread or diffuse on the film. This causes a lack of sharpness, but the latest examples of Technicolor indicate that this has been almost completely overcome. Incidentally, the process can easily be adapted to three-color work if need be: and there is reason to believe that it soon will be, if it has not already been.

And now comes Multicolor, a color system which is attracting world-wide attention because with it neither special cameras nor additional lighting are required. This color company has introduced a new *Rainbow Negative* during the past year which is of far-reaching importance for it brings an already highly perfected process into exact production equality with existing monochrome practice. In short, by obviating the necessity of special cameras and additional lighting it gives color on a black and white basis. Multicolor is at present a two-color, subtractive process which may be employed in any standard motion picture camera using demountable outside magazines. Aside from the use of a special double magazine, and a slight adjustment of the film-gate, there is absolutely no alteration to the camera. The prints may be projected in any standard projector. The secret of the process is its double negative which serves at once as film and filter.

Instead of securing the two necessary color-separation negatives by the use of prisms or rotary filters, Multicolor uses two films, which are exposed together, with their emulsion surfaces in contact. The front negative records the blue-green components of the scene, and has incorporated in the outer surface of its emulsion an orange-red dye which is photographically equivalent to the No. 23-A Wratten filter, and acts as such for the rear film, which is practically a standard Panchromatic, and records the orange-red components only. Since no prisms are used, the negative images are naturally in perfect register, and can be made critically sharp. Since they are made simultaneously, there can be no "fringing". The laboratory treatment of these twin negatives is exactly identical to that of black-and-white negatives. The prints are made on a special, double-coated positive stock. This has an emulsion coated on either side, in each emulsion being also a yellow dye to prevent the fogging of the opposite print. The print is developed in the normal manner, and the two sides are colored, one orange-red, and the other blue-green. The actual toning process used is an ingenious combination of chemical and dye-toning, selectively coloring the respective images. Since the print is not made by dyestamping, and since the original negatives can be made perfectly sharp, a Multicolor print can be made as critically sharp as could be desired. When colored and dried, the print is carefully varnished, and is thereafter ready for duty. This varnishing process is of the utmost importance, for it not only protects the emulsions, greatly increasing the useful life of the print, but also protects the sound track from the dirt, scratches, and abrasions which so frequently ruin the sound far ahead of the picture.

In this printing process, an amazing amount of control can be exerted over the qualities of the finished picture. Not only can the overall density of the print be varied, as with black-and-white, but the color balance as well. While, obviously, there is only *one* "right" balance of color for any given scene, in case of need the balance can be artificially altered to fit the mood: an increase of the red print tending to warm the scene up, and an increase in the blue to cool it.

The new *Rainbow Negative* does not alter any of these processes, but serves to improve the color rendition very noticeably, and increases the overall sensitivity of the process to exact equality with black-and-white. This makes it possible to handle Multicolor in production in exactly the same way as black-and-white. *Anything that is possible in monochrome is equally possible in Multicolor with no other change than the use of Multicolor films and the adjustment of the camera gate to accommodate the two films.* No additional lighting is required, nor any special arrangements: every lighting effect used in normal production can be used unchanged in Multicolor. Extreme high-key and low-key lightings can be used exactly as in monochrome, as can every imaginable trick of artistic camerawork, including glass shots and front miniatures. In addition, by the use of colored gelatines on the lights, an almost unlimited range of absolutely new artistic effects can be produced.

The writer has seen a number of such shots, the beauty of which so far transcended anything heretofore accomplished in either monochrome or color, as to convince him that an entirely new field for artistic cinematography has been discovered. One scene in particular is memorable: representing a mediæval prison cell, and photographed in extreme low key, the interplay of the cold, blue moonlight shining through a barred window upon a beautiful woman within, and the mellow, golden glow of the candle-light from within the room was without doubt one of the most strikingly beautiful scenes ever put on the screen—and one which would be impossible by any other method. Closeups, made either with or without a diffusion-disc, were so startlingly natural that it was hard to believe one was looking at mere colored shadows.

The extreme latitude of the process was well demonstrated by some scenes taken late in the afternoon on an extremely shady street set, but in which the shadows were full of detail, and the highlights none the less absolutely natural. Another scene, made in the desert, pamming around from a very flat front-lighting to an almost complete back-light, showed even less change of density than monochrome would under the same circumstances. But the greatest step of all is the fact that Multicolor has achieved the hitherto impossible feat of making slow-motion pictures in full color! Since the introduction of the new *Rainbow Negative* numerous tests have been made under varying light conditions and with camera speeds as high as eight times normal, with perfect success. The results, in fact, were definitely better than the average of ultra-speed monochrome, but with perfect color added. By virtue of its simplicity, Multicolor offers the whole industry the boon of perfected, workable color, for not only may it be used by the greatest producing companies, but by individual industrial firms as well. There is a surprisingly great field for color in modern industrial filming, though not enough to justify the vast cost of special cameras and apparatus whose use would be limited solely to color work. In this field, Multicolor, requiring only a special magazine and film, is supreme, for once the film gate is adjusted to Multicolor work, any Bell & Howell or Mitchell is at once a color and a monochrome camera, for either process may be used without further change.

Other experiments, too numerous to mention, are being conducted in various quarters. What the future holds for them is a problem. Undoubtedly some promise interesting developments. Among the most interesting is the three-color Keller-Dorian process, which in the 16-millimeter field is known as Kodacolor. For some time experiments have been under way to apply this to the professional field, but to date it has not proven practical.

Without doubt, the coming year will see remarkable strides in the color field.

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HAL HALL, *Editor.*

THE ANCESTRY OF SOUND RECORDING

*H. G. Knox**

THE silent screen's first story dates back to 1903 to "The Great Train Robbery." Every succeeding year for a quarter of a century brought forth some new step, some progress in story or production or both. Three or four years ago most of the novel themes and treatments had been tried. The simple pictures had grown into productions costing millions of dollars. There seemed no end in sight. In that extremity any novelty had an appeal. Sound as an aid to pictures had always been in mind but in recorded form it had never been a success. The motion picture industry was puzzled and was in a receptive mood for treatment.

In certain southern states the witch doctor still exists. In his community the conjurer is a most influential person. Problems presented to him are endless, and range from bringing together two lovers to putting away an obnoxious person. Much of the conjuring is done with magic potions.

Take the horn of a toad, the fang of a snake, some graveyard dust, all mixed together with the blood of a dog. Make into a cake, burn the cake over a charcoal fire, wrap the ashes in red flannel and place under the houses of the victims. This is very strong medicine and immediate results are guaranteed.

Two or three years ago the motion picture industry visited the conjurers of the East. The electrical witch doctors made a brew—a strong one. It contained, among other ingredients, the horn of a radio, the needle of a phonograph and some studio dust. All of these elements were moistened with the tears of a producer and made into a record. The record was cremated in an electrical laboratory, the ashes wrapped in a film of celluloid and placed on the doorstep of the motion picture industry. The intent of the magic was merely to bring the two lovers, sound and silver screen together. As of historical interest it may be remarked that the parents of the silent screen almost suffered a nervous breakdown during the courting and early married days of the young couple.

In referring to the horn of a radio, the needle of a phonograph, one does not exaggerate because actually the "talkie" as we know it did not descend from the attempts of the early inventors to produce talking motion pictures; it came down through a number of

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other sciences and devices, and owes almost nothing to the earlier attempts in the talkie art. Edison contributed much to the sound picture of today but his contribution came through the phonograph rather than through his own sound picture attempts as represented in his Kinetophone and his Cameraphone. The incandescent lamp invented by Edison is also an indispensable component of the modern talking picture machine. The casual historian of the talkie is apt to refer to these early talking picture ventures, such as Edison's, and then jump lightly to the talkie as we now know it. The early talkie experiments themselves left no trail, but in the days when they were being attempted, the real talkie development in other fields had its beginnings.

Every industry has periods of apparent development and periods of apparent stagnation. Often in the quiet intervals basic ideas are being developed which later make possible spectacular achievement. For long years the talkie outwardly stood still. Its sudden attainment of commercial success was, however, but the culmination of a long period of incubation. The talkie is not a primary development. it is an hybrid of other growths.

In 1857 Leon Scott, in France, recorded sound waves on his phonautograph but he could not reproduce sound from his wavy line on smoked paper.

In 1877 Thomas A. Edison announced the successful recording of sound on a cylinder coated with tinfoil, and even more important, the reproduction of sound therefrom. Much time, thought and patient research were put into this device, to be known as the phonograph. The next two important developments in the phonograph were: first, the introduction of wax in the form of a cylinder or disc as the substance on which the record was engraved, and second, a method of duplicating records in any desired quantity from the wax.

Because of the inability to play it more than a few times before it wore out, the original wax cylinder was obviously of no commercial value, and without duplication it could serve but few listeners. At this juncture the electrotyping art came to the aid of the phonograph and made possible by successive electroplating steps, the production of the stampers under which the flat disc records are now pressed wholesale.

In those days bear in mind that the sole source of power available to cut the record in the wax, and later to reproduce the audible sounds therefrom, was in the case of a speaker, the power of his vocal cords. The average vocal power of a human being is only ten-millionths of a watt—an amount of energy hopelessly impotent when it comes to cutting an adequate groove in a record. More power was needed, but was not then forthcoming. At that point, for the time being, the phonograph stood still. The airplane of Langley was a success as to wings and body, but like the phonograph, lacked a power plant.

In 1876, in an improvised laboratory in Boston, after weary months of labor, Mr. Alexander Graham Bell said over an electric wire to his co-worker, Mr. Thomas A. Watson, in an adjoining room—"Mr. Watson, come here, I want you." On that March day the telephone was born. It would be a needless waste of time to appraise the importance of that event, nor is it necessary to outline the developments in the art of telephony. In the course of this development, however, came the modern transmitter, the receiver, the lines, switchboards and other instruments that now contribute so vitally to our daily life. Local telephone service came into being, but beyond limited distances the voice could not be urged. However, much they had improved the local instruments and loaded the lines, the engineers were unable to "push" the speech to any considerable distance over a single pair of copper wires, even though the wires were large. As had the phonograph, here the telephone stopped, and for the same reason—for want of power.

Back in 1867 Clerk Maxwell in England prophesied that one day a phenomenon, involving the transmission of electrical energy without conductors, would be discovered. In 1887 Heinrich Hertz fulfilled Maxwell's prophecy by transmitting in a laboratory electrical energy without wires. The so-called Hertzian waves made the radio prophecy a reality. Marconi and others of illustrious name developed this science to point where relatively large amounts of energy could be emitted from a sending station, but the imperfect coherers and other devices used at the receiving end were unable to detect and magnify the very small amounts of energy up to a point of audibility. Thus we find three epoch-making marvels—the phonograph, the telephone, the radio—all willing tools, but in the most literal sense of the word, "powerless." This was truly a period of stagnation, and from what direction help was to come no one knew.

Largely in Germany physicists and chemists during the foregoing years had discovered that the conductivity of the metal selenium varied with the amount of light shining upon it. These experiments led to the useful selenium cell. When certain metals notably potassium and caesium are spread out in the form of a coating on the inside of a vacuum globe a, so-called, photo-electric cell is obtained. For handling the wide band of frequencies in sound reproduction the photo-electric cell has many advantages over the selenium cell and is generally used.

All the diminutives in existence would hardly do justice to the tiny amount of energy a photo-electric cell produces when excited by light, so here is another useful but helpless servant waiting for science to bring to it more power. It is impossible to over-emphasize the standstill in many branches of electrical science at this period, which might well be called the "Powerless" era.

To John Ambrose Fleming, an Englishman, is accredited the invention of the two-element vacuum tube, and to Dr. Lee DeForest, amongst others, its development. DeForest's particular contribution was the addition of a third element to the tube. The DeForest audion came to notice in 1906 and 1907 and was immediately used in the efforts then going on to produce the radio telephone.

The vacuum tube brought a climax in our otherwise dull historical narrative. Our orchestra—having thus far played soft music, will now burst forth in a blare of trumpets and the crash of brass—because on the stage there now appears the principal actor of sound pictures—the amplifier. Here at last on a silver platter was presented to the waiting electrical world, including the *short distance* telephone, the infant radio, and the whispering phonograph, the priceless boon they awaited—POWER. More or less the progress of civilization can be measured in man's success in harnessing power. Tractor-tilling a huge field by one man is, by comparison to the man with a hoe, but a harnessing of power. In the realm of electricity no single device has perhaps meant so much to humanity as the vacuum tube and its resultant amplifier.

In 1915, thirty-nine years after the epoch-making utterance in his little work-shop, Alexander Graham Bell in New York spoke to his old friend, Thomas A. Watson, in San Francisco, once more, saying "Mr. Watson, come here, I want you." On this occasion it would have taken Mr. Watson three or four days to comply with Mr. Bell's request. In the original conversation of 1915, spanning the American Continent, only six amplifiers were used, but the long-distance telephone was an accomplished fact. Today the American Telephone and Telegraph Company uses in its long distance lines nearly fifty thousand amplifiers. The year 1915 also saw the human voice relayed from Arlington to San Francisco, Honolulu and Paris by radio telephone. Through the introduction of amplifiers the fetters which limited the telephone's span on land and sea were loosed, and one may now telephone by wire and radio from continent to continent with distance and oceans o loger a bar.

One man on a soap-box may inspire a small crowd but not a large one. His unaided vocal energy of ten-millionths of one watt is a puny implement. Compare ten-millionths of a watt to the energy of an ordinary 60 watt lamp, for example. Even 60 watts seems little enough. During the latter part of the war, in one of the Liberty Loan drives, New Yorkers will remember Liberty Lane. Liberty Lane was a section of Madison Avenue along which were located loud speakers connected through amplifiers to a microphone. Orators were few; the need for funds was great. One man at the microphone could thus address endless throngs in the street, broadcasting his message of patriotism and thrift. This was perhaps the first conspicuous demonstration of the public address system—a combination of microphone, amplifier and loud speakers. Public address systems were also used indoors at the presidential nominating conventions of 1920 and again outdoors at the inauguration of President Harding in 1921. Radio broadcasting came into being about this time, as stations WJZ and WEAF started their careers.

As far back as 1847 the idea of transmitting pictures over electric wires had been thought of. In 1908 Knudsen in Norway actually did it. True enough, the pioneer attempts were crude but considering the niceties of the devices required there is small wonder. In picture transmission each tiny dot of the original picture surface must be transmitted over wires, and must be deftly placed at exactly the corresponding needle point at the seceiving end and at exactly the same density. Light must be converted into electricity, sent over wires, and reconverted into light. In a number of the larger cities of the United States you can hand a photograph to a telegraph messenger, and an hour or two later have it delivered in another city thousands of miles away. Telephotography is pertinent to our subject because in this remarkable machine, developed by the Bell Telephone Laboratories, we find several of the problems later to be faced in the talkies, and several of the devices for their solution.

The year 1925 deserves a word because in that year electrically recorded phonograph records with reproducers and horns of scientific design placed a lagging phonograph industry once more on commercial feet. Also during the period of 1922 to 1925, successful examples of the modern commercial talking picture were shown. Two experiments of promise were the Phonofilm of DeForest and the General Electric Pallophotophone. In Europe, notably in Germany and Denmark, experiments in talkies had come to light. But posterity is never so much concerned with research and scientific demonstration as it is with commercial success.

On the sultry evening of August 6, 1926, Warner Brothers and the Vitaphone Corporation, at Warners Theatre in New York, showed "Don Juan." There was a stirring orchestral accompaniment but no orchestra. Preceding the feature picture Mr. Will Hays, from the screen, made an address, and songs were sung by Marion Talley, Anna Case and Martinelli. Mischa Elman and Zimbalist contributed with their violins. On that evening a startled audience heard the first commercially successful talking picture in the world. As far as the motion picture industry is concerned, sound came that night to the silent screen.

In January 1927 William Fox showed greatly improved sound recorded on film, and followed not long afterwards with the first movietone news reel, and during 1928 the larger motion picture producers made up their minds that the talking picture had come although as to its future one man's opinion was as good as another's. In 1928 the Motion Picture Industry contemplated the cold, cold water and took its plunge.

Up to this time most of the developments and other happenings had been in the East. Hollywood, left somewhat uncertain as to its future, was still quiet. Things changed. Hollywood, the capital of the silent motion picture world, felt the first rumblings of its reincarnation with a voice. Skeletons of sound stages began to rise, and in Hollywood when things rise, *they rise*. There were few sound experts, none of course with actual talking picture experience, no suitable stories for sound pictures, and the merest beginnings of stages and recording equipment. Shortly after the frantic start came a fire at the Paramount studios which wiped out four sound stages nearing completion. Fortunately the recording apparatus was not damaged. Undismayed, new stages were started and pictures on schedule went ahead in the quiet of the night on other stages far from silent. New men, new tools, new technicians, with a new and puzzling vocabulary, suddenly sprang into existence. The Western Electric plant in Chicago worked extra shifts in manufacturing equipmen. At the end of 1928 Hollywood boasted 16 recording channels in use.

Nineteen twenty-eight faded into twenty-nine. Along with the physical construction of buildings and the installation of recording channels came other problems. Hollywood, long noted for its doctors of beauty culture, added to its activities doctors of voice culture. To an augmented staff of writers came composers, singers and stage actors of note. Silent pictures were fitted wih recorded musical accompaniments. Simple stage dramas were tried on the new machine.

Stars of the silent screen tried out their voices. The period might properly be characterized as one of trial, caution and conservative progress. No one knew for sure the machine, the type of picture or the audience reaction. An outdoor picture or two shook off some of the beliefs that only a sound proof stage would do. A musical comedy added color and life. The advances of 1929, so close behind us, were in reality startling in their value. Nineteen twenty-nine also marked the beginning of what will one day be the high art of sound picture technique. While Hollywood ended 1928 with 16 recording channels, it ended 1929 with 116.

Education is a form of mental gymnastics. Nineteen thirty finds all those contributing to the further improvement and success of sound pictures exercising vigorously. There is no rest in sight. The electrical industry promises better and better recording. Color is here and is improving. If the film industry agrees to it there will probably be a wider film. The "smellie," the "tastie" and the "feelie" are in the offing. In their cases amplification is not only a problem but a menace. So much for the implements of 1930.

In March, 1930, a class of 300 studio representatives was attending the final section of the Academy Sound School. There is now a trained personnel in Hollywood numbering perhaps thousands who in their daily work have to do with the newly tamed sound. Two years ago this army did not exist.

Last, and therefore most important, is the evolution visible in the artistic side. The author, the composer, the producer, the director, the actor—all those whose talents feed the "mike"—they too are becoming sound-wise. Some day soon, perhaps in 1930, a talking picture epic will come along. In that film subtle dialogue, exciting silence, eloquent effects will be blended by director and actor into a never to be forgotten sensation.

Descended from the telephone, the radio, the phonograph, sound is adding its might to the silent screen. The resulting dictator of public thoughts and tastes, giant both by heredity and public appeal, is preempting a rare and influential place in the sun.

THE NATURE OF SOUND

*Professor A. W. Nye**

It is our purpose in these introductory lectures to describe and discuss the fundamental principles and phenomena of sound, particularly those which enter importantly into the problems of recording and reproducing, so that succeeding lecturers may present to you their use and application to the work of the studio.

We are concerned, first of all, with the origin and nature of sound and how it travels from place to place; after that with its reflection, refraction, diffraction, absorption, interference; with its effects on diaphragms, human ears, and other things which it strikes; with methods of making the sound create a similitude of itself in the form of a varying electric current or a varying light beam; with the reversal of this action into sound again; with the considerations of what are the causes of "quality" in tones; and with many other phenomena.

In order to get a mental picture of the way in which sound originates and travels, we might imagine a very long horizontal pipe having a light, snugly fitting plunger at one end and a great many pressure gages attached along the pipe. Suppose that these gages are made so as to indicate pressures either above or below normal atmospheric pressure.

Then if we cause the plunger to be moved quickly forward, then backward an equal amount, and finally returned to its original position, and if we watch the pressure gages during this action, we will see gage 1 first show an increased pressure, then 2, then 3, and finally the last gage. But we will also notice that by the time the increased pressure has reached the gages part way along the pipe, the readings of earlier gages have decreased and some have even reversed their readings and show a pressure less than normal, due to the decrease of pressure caused by the backward motion of the plunger; so that at

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a given instant we might see gages in all sorts of stages. If we make a graph of gage readings for such a condition it might resemble *Fig. 1*.

In this diagram the locations of the gages are represented

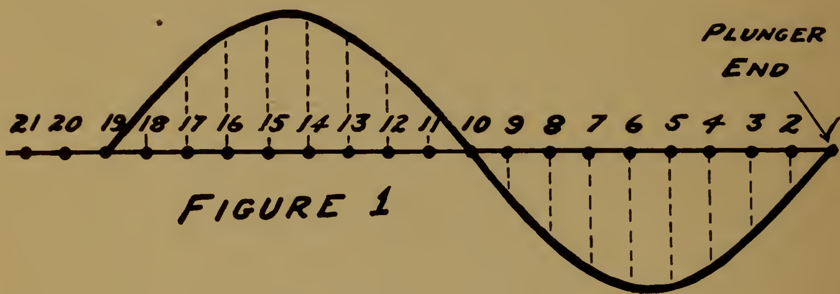

FIGURE 1

by the black dots and their readings of pressure above or below normal are represented by the lengths of the dotted lines. Thus the diagram shows that the pressure wave has just reached gage 19, but all gages beyond it are as yet unaffected. Gage 15 is at its greatest pressure above normal, while such gages as 13 and 12 have reached their highest values and dropped down again; 10 has dropped back to normal and gages 9, 8, 7, etc., are showing the effects of backward motion of the

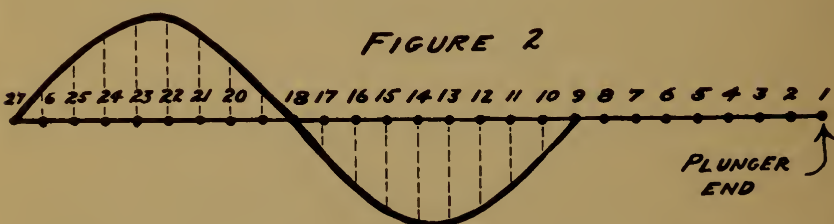

FIGURE 2

plunger; 1 has gone through all stages of the pressure wave and has returned to normal.

If we were to represent the situation a short time later it would look like *Fig. 2*.

The wave of pressure has moved to the left and all the gages up to 9 have returned to their normal readings. At later and later times, this same situation would be found at regions farther and farther to the left.

If we were to measure the speed at which this pressure wave travels we would find it to be about 1100 feet per second; and if an ear were placed at the far end of the pipe it would eventually notice the pressure wave as a sort of "tut."

Now suppose that the plunger is kept oscillating at a regular rate, say 100 complete oscillations per second. Then a series of pressure waves just like the above, would follow each other down the pipe and eventually the ear would receive them at the same rate as they are produced, viz., 100 per second. The ear would judge this action as a *tone,* in this case of rather low pitch. If the rate of oscillations be increased to several hundred per second, then the ear would give the sensation of a tone of higher pitch, and we might carry this idea to vibrations of several thousand per second.

We find, by experiment, that the speed of travel of these pressure waves is the same no matter what the frequency of oscillation. At first thought we might imagine that the waves of greater frequency would travel faster, but this is not true.

The action of these pressure waves just described is "sound." In most actual cases, of course, the propagation is not inside of a pipe but out in more or less open air. There would be no essential differences in the action, although there would be a very slight difference in speed. We might think that in free air the variations in pressure could not occur on account of lack of confinement, and it certainly is true that great variations would be difficult to produce in free air, but we find that the amount of variation, above and below ordinary air pressure, which is needed for the ear to recognize, is exceedingly small. Even changes as small as a billionth of the ordinary pressure are detected by the ear, if coming at a rate within a range of about 20 per second up to about 25,000 per second.

Returning to the conditions inside the pipe, while the plunger is vibrating we see that in a long pipe there might be many waves of pressure present in the pipe at the same time, and we are accustomed to call the distance from one wave to the corresponding part of the next wave, the "wave-length." For low frequency the wave-length is long and for high frequency it is short. The two are always so related that the product of

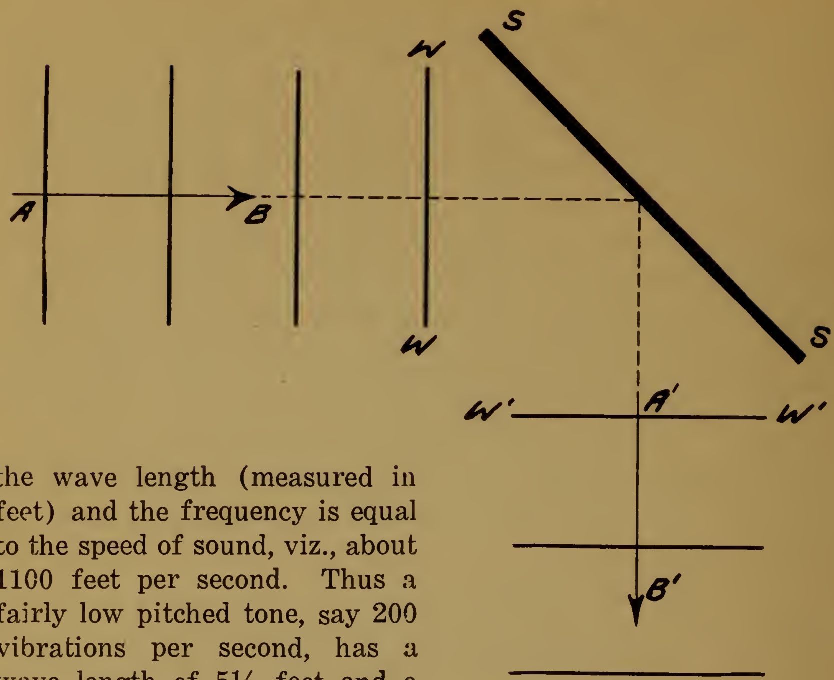

FIGURE 3

the wave length (measured in feet) and the frequency is equal to the speed of sound, viz., about 1100 feet per second. Thus a fairly low pitched tone, say 200 vibrations per second, has a wave length of 5½ feet and a high pitched tone, say 5500 vibrations per second has a wave length of .2 feet.

We have now established what we mean by frequency, pitch, wave length, speed of sound.*

The next idea is that of loudness. This is found to depend on the distance through which the plunger (or other vibrating body which sets up pressure waves in the air) moves back and forth. The greater is this movement, the greater is the loudness. Here again we find that extremely small movement causes great aural sensations and the actual excursions of a vibrating, sounding body, or of the air particles involved in the propagation of sound, are very very small fractions of an inch. In some types of microphone the movement of the diaphragm does not exceed .0001 inch.

Sound may be propagated in solids and in liquids in a manner similar to that in air.

**Accompanying the lectures on THE NATURE OF SOUND as given before motion picture studio employees enrolled in the Academy School in Fundamentals of Sound Recording extensive demonstrations were made. These included the use of charts, slides, illuminated ripple trough, projecting oscillograph, amplification of specially prepared records, etc.*

WAVE FRONTS

If sound were started from a small vibration out in open air, the pressure waves would spread out in all directions and the

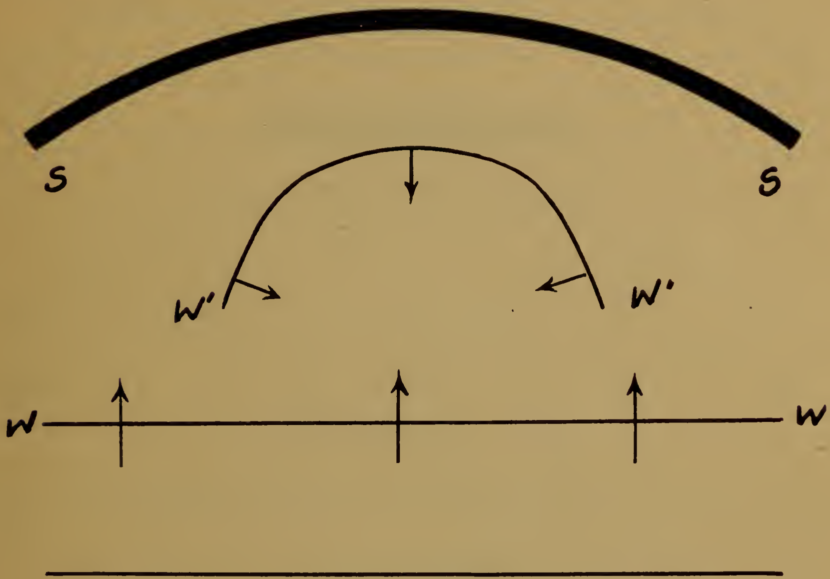

FIGURE 4

"wave-front" would be a curve, whose center is the vibrator. As the sound goes farther and farther any small portion of this wave-front becomes more and more straight or flat and we come to speak of *plane* waves.

REFLECTION

If the sound wave-front strikes some hard surface it is reflected and its direction is changed.

Thus if WW *(Fig. 3)* represents one of a series of wave-fronts proceeding in the original direction AB and striking a reflecting surface SS, then W′W′ shows the wave-front after reflection, going in the direction A′B′.

Or, if the reflecting surface is curved, the action may be as in *Fig. 4* where there is a tendency toward focusing or concentration.

The result of reflections is often to give the effect of a sound coming from behind a surface or from a direction very different from the real direction of the source of sound; in other cases it results in echoes, or in confusing overlapping of

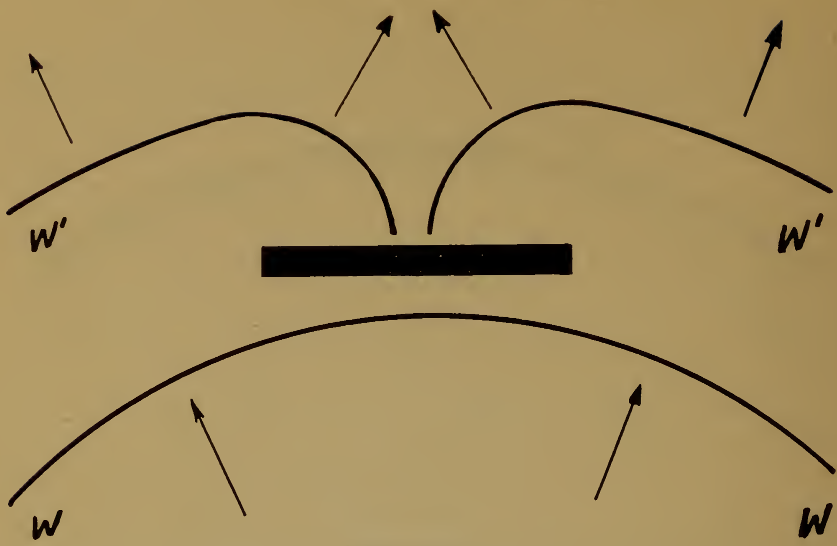

FIGURE 5

earlier sounds on later ones, or in excessive concentration of sound at certain points.

DIFFRACTION

Sound waves are usually of considerable wave length, and when they strike a small obstacle, instead of being reflected they are diffracted and bent around the corners. This is shown in *Fig. 5*.

Diffraction also takes place when a small aperture is encountered, as shown in *Fig. 6*.

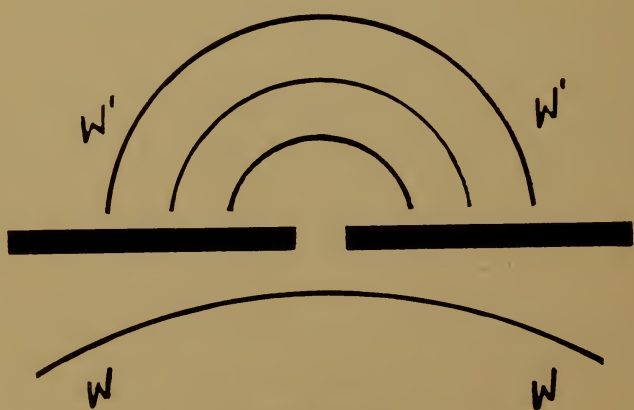

FIGURE 6

This gives a wave spreading from the aperture as though it were a source of sound itself.

REFRACTION

Refraction or change of direction, takes place when the wave meets a new region in which the speed is different. For example, a wind may be blowing parallel to the ground and having a low speed near the ground and a high speed at greater altitudes. This will affect the speed of sound and therefore change the direction of sound as shown in *Fig. 7*.

A similar result may come about when sound encounters air

FIGURE 7

strata or regions where the temperature is variable. Temperature affects the speed of sound in air.

INTERFERENCE

Two sound waves may meet at certain places in such a way that the tendency of one to produce increased pressure may be aided by the other, or neutralized by the other. In one case the result is increase of sound, in the other case decrease of sound. In general these effects vary greatly from point to point in a room.

The production of interference depends greatly on wave length, so that if sounds, involving many different frequencies, arrive from two different points they may meet at a given place so that some frequencies aid while others neutralize; and at a place near by, the reverse may be true. Thus at certain spots in a room some frequencies may disappear and others be greatly increased in intensity. Dead spots may be caused in this way. Again, in the throat of a loud speaker horn, waves from various parts of the diaphragm may meet so as to neutralize, thus causing the horn to cut off at a certain frequency.

SOUNDING BODIES

In general, sounds may be produced by irregular vibrations of bodies as well as by regular vibrations. Often we call the irregular ones noises, and the regular ones musical tones, but the distinction between pleasant and unpleasant, wanted and unwanted sounds is not so simple as this. Noises and tones have the same general physical characteristics and obey the same laws.

But there are many well defined cases where the vibrations are regular, although they may be somewhat complicated.

STRINGED INSTRUMENTS

In the case of the stringed instruments, including the piano, instruments of the violin family, plucked string instruments, and others, the vibrations of the strings are communicated to the body or sounding board and thence to the air. But the strings always vibrate in a complicated manner resulting in the establishment of a "fundamental" or lowest tone, plus a series of "overtones." The fundamental is due to the vibration of the string as a whole, while the overtones are due to the vibration of the string in parts.

The overtones are tones of higher frequency than the fundamental and generally are simple multiples of the fundamental frequency, such as two, three, four, five, etc., times the frequency of the fundamental. In the case of the G string of the violin, overtones may be distinguished which have as many as 15 times the frequency of the fundamental.

The overtones are present in varying degrees of loudness in various instruments. They give brilliance or "quality" to the tone and cause the distinction between tones from different kinds of instruments. If these overtones are omitted from the sound recording (due to failure of the equipment to record certain ranges of frequencies) then important characteristics of the tones are lost and the ear recognizes that fidelity has not been attained. It can be demonstrated that the elimination of overtones causes the tones of various musical instruments to resemble each other.

WIND INSTRUMENTS

The wind instruments include the brass wind and the wood wind. In the former class we find the cornet, trombone, bass horn, French horn, saxophone, and others. In the wood wind class we find the flute, clarinet, oboe, and others. In both classes we find instruments with cupped mouthpieces and instruments with reeds. In all cases there is an air column which acts as a resonator.

RESONANCE OF AIR COLUMNS AND VOLUMES

Usually, in order to get a loud clear tone, it is necessary that the action of the original source of vibrations be supplemented by a resonator. Although a resonator does not in itself add or create any energy, it usually does act in such a way as to allow the vibrator to generate a greater amount of energy by giving it an impedance to work against. Thus the air in the horn of a loud speaker acts as a "load" on the diaphragm and enables us to put a greater amount of energy into the system than if the diaphragm vibrated in free air. Resonators may consist of sounding boards like those in pianos or the bodies of violins (in which cases they respond almost uniformly to any frequency which may be impressed on them) or they may consist of columns or volumes of air.

Air columns, if narrow, respond to vibrations of different frequency depending on the length of the column.

If the column is open at one end and closed at the other it will respond to tones of such frequency that the length of the column is ¼ of the wave length. But it also responds to tones such that the length of the column is 3/4, 5/4, 7/4, etc., of other wave lengths. If the column is open at both ends, as in the case of most musical instruments, the response will be to tones for which the column length is 1/2 wave length, 2/2, 3/2, 4/2, etc. Thus, any air column may respond to many different frequencies and will do so *simultaneously* if the various frequencies are present in the original vibrations.

Thus we again find the results containing a "fundamental" plus a series of "overtones."

The simple motion just given is modified by "end corrections," by sloping sides and flared ends, and by other conditions.

Air masses, such as occur in the human throat, mouth, and nasal cavities also may act as resonators. The action is here largely dependent on the volume and the elastic properties of the air.

In wind instruments with reed mouthpiece, the reed vibrates and thus generates a series of air pulses which are regulated and resonated by the air column. In the human voice the vocal cords resemble this action somewhat, with the additional feature of muscular control, which adjusts the rate of vibration.

In the cupped mouthpiece instruments, the stretched lips play a similar role, with the help of the tongue.

In all cases the final tone elicited by the instrument is composed of a fundamental along with a series of overtones or partials. These latter are present in varying intensities, sometimes even greater than the fundamental.

With the flute the fundamental is very strong, the second and fourth partials are somewhat prominent and the remainder very weak. The clarinet shows a fair intensity for the fundamental along with strong eighth, ninth, and tenth partials. The oboe has weak fundamental and strong fourth and fifth, weak sixth partials. The brass horns often show many upper partials of considerable intensity.

These mixtures of partials make the various instruments have their characteristic quality and if the recording and reproducing change the relative intensities, the resulting sound does not have fidelity.

The resonating qualities of the mouth and throat are strikingly illustrated by the use of the artificial larynx. This is a small vibrating reed device which is supplied with air pressure from bellows and inserted in the mouth of persons who have lost the larynx due to surgical operation. The vibrating reed pipe arrangement supplies the air pulses and if the person regulates

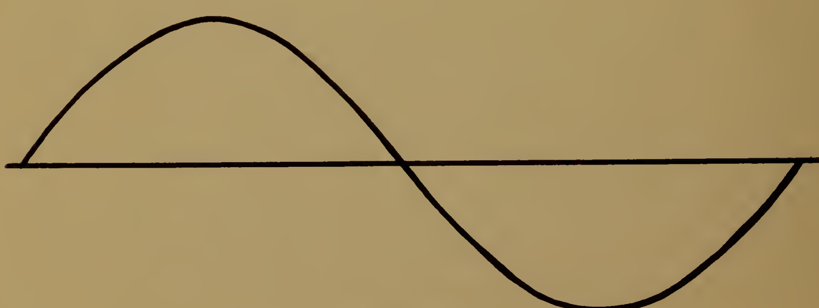

FIGURE 8

his throat and mouth cavities in the usual way, they act as suitable resonators and the vowels and consonants may be enunciated in a very intelligible manner.

Another illustration is given by the action of a strong wind

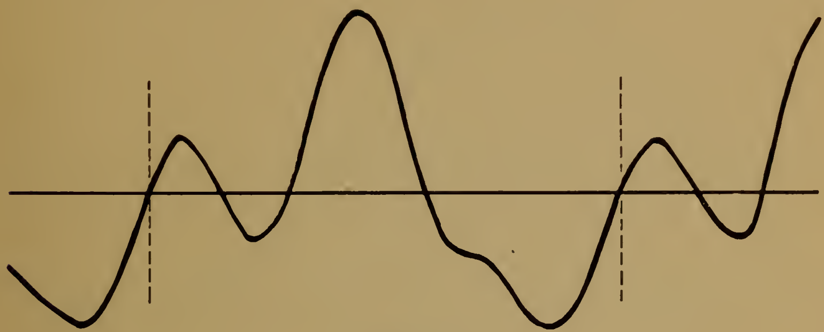

FIGURE 9

across the mouth when adjusted for "oh." This sound will be generated quite prominently without use of the vocal cords at all.

ANALYSIS OF SOUNDS

Devices have been constructed which give us a record of the pressure wave of any sound.

In the case of a very simple tone, like that of a tuning fork, where the fundamental alone is present, the record shows as a smooth wave; as in *Fig. 8.*

But in most cases it will be more complicated, as in *Fig. 9.*

It has been found possible to analyze all such curves into simple components. For example, in the case just illustrated, the analysis shows that three simple components were present. (See *Fig. 10.)*

The analysis in *Fig. 10* shows a fundamental tone (1) and two overtones or partials, (2) and (3), both of considerable intensity. As a check on such an analysis we may add together the three components (having regard to plus and minus pressure values) and, if the original curve is obtained, the analysis was correct.

Theory and practice show that there is only one analysis for a given curve and many facts lead us to believe that the ear hears the original sound just as if it had consisted of the separate individual tones shown by the analysis.

A very interesting and important result of this is the fact that in case the recording and reproducing equipment does not respond in exact relation to all the ups and downs of the original sound curve, then the resulting sound curve will be different from

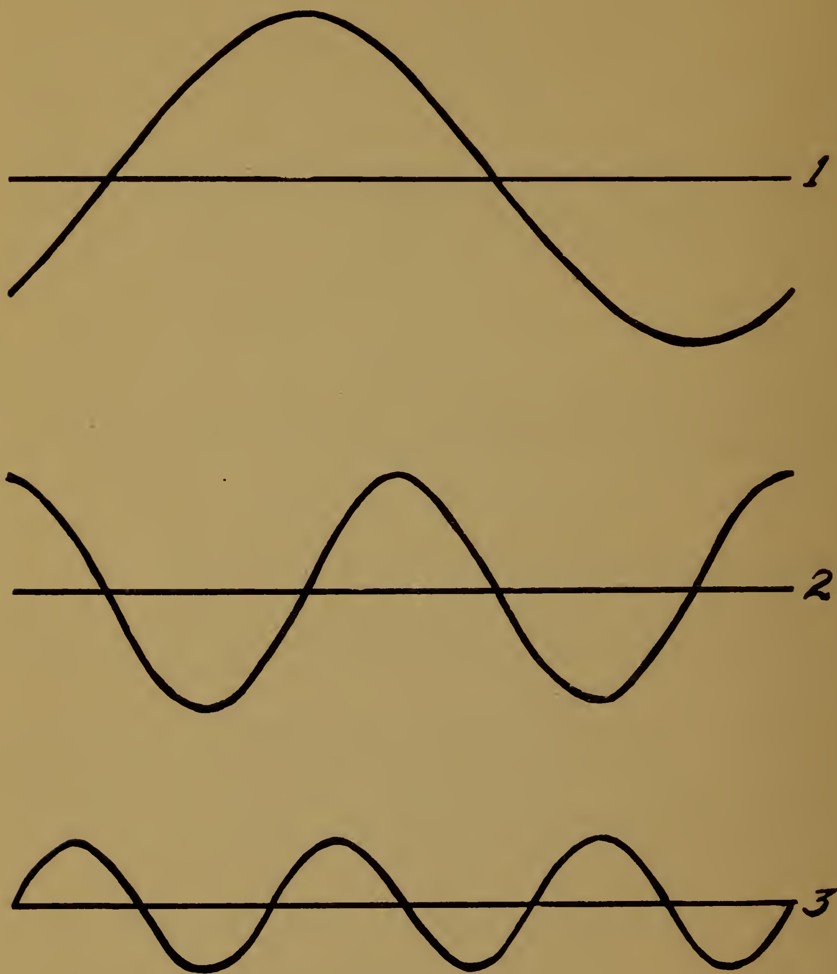

FIGURE 10

the original and its *analysis will be different.* In most cases, this analysis will involve components which were not present in the original and thus the ear will hear frequencies which did not originally exist. Thus, "spurious" frequencies are introduced. This is known as "non-linear" response and gives a different type of distortion from "frequency" distortion. The latter merely gives too much or too little response to certain of the original frequencies but does not introduce any new or spurious frequencies.

Most of the sounds of voices and instruments have a wave form which is much more complicated than the one used here for illustration.

It will be noticed in *Fig. 10* that components 1 and 2 do not start in the same "phase." That is, they do not cross the horizontal axis at the same time. If we were to shift the three components so that they all cross the axis together at the left hand side of the figure, and then add them together, the result would be a curve which would *look* different, but actually would represent the same sound so far as the ear is concerned.

In other words, the ear appears to be affected by the various component frequencies which make up the entire sound, without regard to the *phases* of these components.

A projecting oscillograph can be used to demonstrate the character of the wave form of various voice and instrument tones. Also some specially prepared phonograph records have been made by the Bell Technical Laboratories and the Victor Company to show the effects of non-linear response and the effects on music and speech of eliminating certain frequency bands.

COMBINATION TONES

When two tones, of nearly the same frequency are sounded together an effect called "beats" is produced. This is a waxing and waning or throbbing effect caused by the two tones alternately helping and destroying each other. The number of beats per second is equal to the difference of the frequencies of the two tones. Thus if one tone were 200 double vibrations per second and the other were 202, then there would be two beats heard per second.

When the number of beats per second reaches a higher value, the effect may be that of a new tone whose frequency is that of the beats. This can be demonstrated by means of a whistle having two barrels. Each alone may give a high pitched tone, but together the effect will be a low pitch which depends on the difference in frequency of the two high tones. The same effect is used by organ builders to obtain low tones without the use of long pipes.

"Summation" tones are also heard under certain circumstances and are due to the production of a new tone having a frequency equal to the sum of the frequencies of the original tones.

VARIATION OF INTENSITY WITH DISTANCE

In free air the intensity of sound falls away in proportion to the square of the distance. Thus the intensity at 50 feet is one-fourth of that at 25 feet. But in rooms there is a marked tendency for reflections from floor, walls, ceiling, etc., to maintain the intensity at remote points.

INSULATION, TRANSMISSION AND ABSORPTION

Sound is transmitted best by homogeneous media. If air is non-homogeneous due to clouds, fog, irregular currents, etc., sound transmission will be interfered with, and the same action takes place in solids. Insulation of sound is thus enhanced by discontinuities such as alternating layers of solid and air, and hard and soft materials alternately in contact in all type of construction. Very solid and heavy construction will serve to prevent sound from setting up vibrations.

Absorption takes place where material is porous and considerable air friction is produced. It also takes place when inelastic masses are set in motion by the sound.

Recent tests have shown improved absorption of walls when a perforated front wall is set in front of a rear surface of felt, an inch or so of air space being left between. The air holes and pockets cause friction and also produce absorption due to certain resonant actions.

CONVERSION OF SOUND INTO OTHER FORMS

Sound has been described as a moving pressure wave, or series of waves, in the air (or in liquids or solids). It thus involves a *mechanical* motion of the medium in which it travels.

When a sound strikes the diaphragm of a transmitter or microphone it makes the diaphragm move to and fro in the same wave form as the sound itself, and the arrangement in the microphone is such that this motion of the diaphragm *causes an electric current to vary,* in exactly the same way, so that we now have the variations of the electric current substituted for the original sound.

This varying electric current can be transmitted over wires but, of course, it is no longer sound. However, it can be reconverted into sound by devices like receivers and loud speakers.

One of the problems of the sound engineer is to make this electric current vary in exactly the same pattern or wave form that characterized the original sound. Also, since the current variations produced by the sound are very small, another problem is to amplify them and still keep them true to the original wave pattern, in other words to have "distortionless" amplification.

In an ordinary telephone system, the message travels as a varying electric current in the wires and is not reconverted into sound until it reaches the telephone receiver at the far end of the line.

In a sound studio, this varying electric current may be put to work in various ways. It may operate a stylus which cuts a wavy groove in a wax disc, it may operate a light valve which allows a varying amount of light to fall on a moving film, it may move a small mirror and cause a beam of light to trace a wavy line on a film, it may control the glow from an Aeo light, or it may be made to control other devices. In any case, whatever it accomplishes must be a true facsmile or similitude of the way in which the air pressure varied in the original sound. The sounds from an orchestra or a chorus or from a single voice produce an exceedingly complicated wave pattern and the duty of the recording apparatus is a difficult one.

ARCHITECTURAL ACOUSTICS

*Dr. Vern O. Knudsen**

1. *Introductory.* Probably one of the least understood, and yet one of the most important, problems in the recording and reproduction of sound is the acoustic adjustment or control of the spaces in which the sound is recorded and reproduced. The acoustic design of the talking picture set is particularly subject to wide variations, dependent upon the skill of the technician, and the requirements of the art director. There is a great deal of empiricism in the selection of the set materials, in the determination of the shape and size of the set, and in the location of the microphone. Consequently, there is a greater likelihood for violating the rules for good recording in the acoustic design of the set than there is in the control of the recording equipment which is much more standardized and less subject to human error.

It is not the object of the present paper to discuss to any great length the acoustic design of sets. Rather, the purpose of this lecture is to outline in the simplest possible manner the fundamental facts which are pertinent to the proper control of sound in closed or semi-closed spaces. If the recording engineer be familiar with the fundamental principles of architectural acoustics, his problems in the studio will likely be attacked and solved in an orderly and scientific manner rather than in the empirical method of "cut and try".

The securing of satisfactory acoustics in an enclosed space is a straightforward engineering problem. If it is worked out in accordance with the known facts of architectural acoustics, the outcome is determinable and can be made to meet the most

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exacting requirements. There is no warrant for the superstition, or belief, still held by many that the acoustical qualities of an interior cannot be known until the structure is completed. It is true that difficulties may arise during the design or construction of a building, because of the limitations imposed by good acoustical design, but there are devices and materials the proper use of which will overcome the difficulties and secure entirely satisfactory results.

2. *The hearing of Speech in Enclosed Spaces.*

(a) *General Considerations.* We shall first consider the limited problem of the hearing of speech in auditoriums. This is not only one of the most important asɒects of architectural acoustics, but it is a problem which I wish to discuss in some detail because it will illustrate the value of scientific research in solving a specific problem in acoustical design.

Perhaps the most important single factor which affects the acoustic qualities of an enclosed space is reverberation. When sound is generated in an enclosure it is reflected back and forth by the boundaries until the sound energy is all converted into heat. The persistence of sound in a room after the source of the sound has been stopped is called reverberation. The time of reverberation is a measure of the time required for a sound to die away to one-millionth of its initial intensity; that is, the time required for the sound to be reduced in loudness 60 db. Ordinarily the time of reverberation is referred to a tone of 512 d. v., although it is necessary to know the time of reverberation for tones of all pitch used in speech and music, namely from about 50 d. v. to 5000 d. v. If the time of reverberation in an enclosed space is long, say several seconds, the successive sounds of speech or music remain audible so long that they overlap and confuse. The method of calculating and controlling the reverberation in rooms has been largely worked out by W. C. Sabine. The actual method of carrying out the calculations will be given later in this lecture.

Ever since the monumental work of W. C. Sabine on reverberation there has been a growing tendency, especially in America, to rate the acoustic quality of an auditorium almost solely in terms of its time of reverberation. It is true that reverberation (which determines the rate of growth and decay of sound in a room) has been, and yet is, the most important factor in determining the acoustic properties of a room. However, reverberation is not the only factor affecting the acoustic properties of an enclosure. Thus, the size and shape of the room, and the presence of extraneous noise, all contribute to the resulting acoustic merit of a room.

It is not a simple matter to give a quantitative rating to a room which is to be used for music, since so much depends upon the musical taste and disposition of the listeners. It is, however, a relatively simple matter to give a quantitative rating to a room which is to be used for speaking, since our primary concern is how well we hear the spoken words of the speaker. The most feasible scheme for such a rating is probably the one used by telephone engineers for testing speech-transmission over telephone equipment, which goes by the name of "articulation tests". The method of conducting articulation tests was described in the lecture on "Speech and Hearing". This method has proved to be very useful for investigating the effects of noise and reverberation upon speech reception in auditoriums.

The "percentage articulation" in any room signifies what percentage of typical speech-sounds can be heard correctly by an average listener in that room. A speaker calls out typical monosyllabic speech-sounds, in groups of three, at a rate of three syllables in two seconds. Observers stationed in representative positions in the room write down what they think they hear. If, on the average, they hear correctly four-fifths of the total number of called speech-sounds, the articulation for this room is rated at eighty per cent. It would seem that such a scheme as this offers a satisfactory means for rating the acoustic quality of a room which is to be used primarily for speaking.

It is obvious that the percentage articulation in an auditorium will depend upon (1) the size of the room, (2) the reverberation characteristics of the room, (3) the amount of disturbing noise in the room, and (4) the shape of the room. It is apparent that, for speaking purposes only, the ideal auditorium is a small room free from all noise, and bounded by perfectly absorbing surfaces. In such a small room the listener will be near the speaker and therefore the speaker's voice will be heard with adequate loudness. Further, there will be no interfering noise, reverberation or delayed reflections. Actual tests conducted in a quiet open place have indicated that with average speakers and listeners the articulation in such a room will be about ninety-six per cent. This figure represents the highest attainable acoustic quality for speech reception in a room. A rating of one hundred per cent, that is perfect articulation, can never be attained. A few of the consonantal sounds are sometimes mistaken even under ideal hearing conditions. We are ordinarily unaware of this when we listen to speech because the connotation of the articulated words facilitates the correct interpretations of those words which are not heard distinctly. Even when the speech articulation is as low as seventy-five per cent the hearing will be regarded as acceptable. An articulation of ninety-six per cent is, for all practical purposes, about perfect, and therefore there seems to be no necessity for attempting to improve this limited ideal, although it could be done by altering slightly the pronunciation, or even emphasis, of some of the soft consonantal sounds.

The extension of the size of the room, the use of reflecting materials for the walls and ceiling, and the presence of disturbing noise will all tend to impair the acoustic quality of the room, and thus reduce the articulation below ninety-six per cent. In general, each of the four mentioned factors which affects the acoustics of the room will introduce a distortion or a disturbance which can be determined quantitatively. Thus, the resulting percentage articulation in any specified auditorium can be estimated by the following equation:

$$\text{Percentage Articulation} = 96\, k_l\, k_r\, k_n\, k_s, \qquad (1)$$

where k_l is the reduction factor owing to the inadequate loudness of the speech, k_r the reduction or distortion factor owing to reverberation, k_n the reduction factor owing to noise, and k_s the reduction factor owing to the shape of the room. The first three of these reduction factors are fairly well known from existing experimental data. The work of Fletcher has determined the effect of loudness upon speech reception, and my own work has determined the effects of noise and reverberation upon speech reception. The effects of loudness and noise were discussed in the lecture on "Speech and Hearing". The interfering effect of reverberation upon the hearing of speech will be discussed later in this lecture. For the present, we wish to ascertain what is the average loudness of speech in a room of specified size, or what is the average power of speakers' voices in rooms of different sizes.

(b) *The average Acoustic Power of Speakers' Voices in Auditoriums.* The data on the effect of loudness upon speech articulation indicate that it would be desirable to maintain the loudness of speech in auditoriums at a level of not lower than 50 db. The question now naturally arises whether the average speaker in an auditorium maintains a loudness level as high as 50 db. It will be seen presently that he does in small rooms, but in large, non-reverberant auditoriums it requires considerable effort on the part of the speaker, and in very large auditoriums it will be impossible to maintain this level without the aid of amplifiers.

The approximate loudness of speech in an auditorium can determined from simple calculations based upon some numerical constants of speech and hearing obtained by Bell Telephone engineers. The data of Sacia and Sivian at Bell Laboratories indicate that the average speech power generated by an average speaker in normal conversation is about ten microwatts. The actual power output of different speakers, and even of the same speaker, varies widely from this average value. For example, they found that the peak power may sometimes rise to two thousand microwatts.

Every public speaker is fully aware that he must raise the intensity of his voice above the ordinary conversational level in order to be heard in a large auditorium. It is evident therefore that his energy output, particularly in very large auditoriums, will be considerably above the average conversational level of ten microwatts. In order to determine the approximate value of the average power of the average speaker's voice in an auditorium, the writer has obtained some measurements on the loudness of speakers' voices in a small and also in a moderately large auditorium. The measurements were made with the help of a microphone (suspended near the middle of the auditorium), an amplifier with an attenuation circuit and a head-set in its output, and a high-quality electric phonograph. The electric phonograph, with a calibrated volume control, was first used for a source of speech in the auditorium. The loudness of the reproduced speech was maintained at different measured levels, and at each level, the attenuation circuit associated with the amplifier (which was located in a remote room) was adjusted until the speech, as heard in the head-set, was reduced to the minimal threshold of audibility. A similar adjustment of the attenuation circuit when a speaker was speaking in the auditorium, gave a measure of the loudness of his voice. The method is essentially a substitution method in which the average loudness of the speaker's voice is compared with a measurable loudness from the electric phonograph. The loudness of the speaker's voice is expressed in db.

By means of known data for the sensitivity of the ear, and the relation between the intensity of sound in a room and the total amount of absorption in the room, it is possible to calculate the acoustic power of a speaker's voice in an auditorium. Measurements and calculations based upon this method and the experiments described in the preceding paragraph, indicate that the average acoustic power of the average speaker in a room having a volume of 27,000 cubic feet is 27.4 microwatts, and the average loudness of the average speaker is 50.7 db. In a large auditorium, one having a volume of 240,000 cubic feet, the average acoustic power of the average speaker is 48.9 microwatts, and the average loudness is 45.7 db. Thus, as the size of the room increases, the speaker generates more speech energy but not enough to maintain as high a loudness level as he maintains in a smaller room. The average acoustic power of the average speaker in rooms of different sizes is indicated by the curve in *Fig. 1.* The

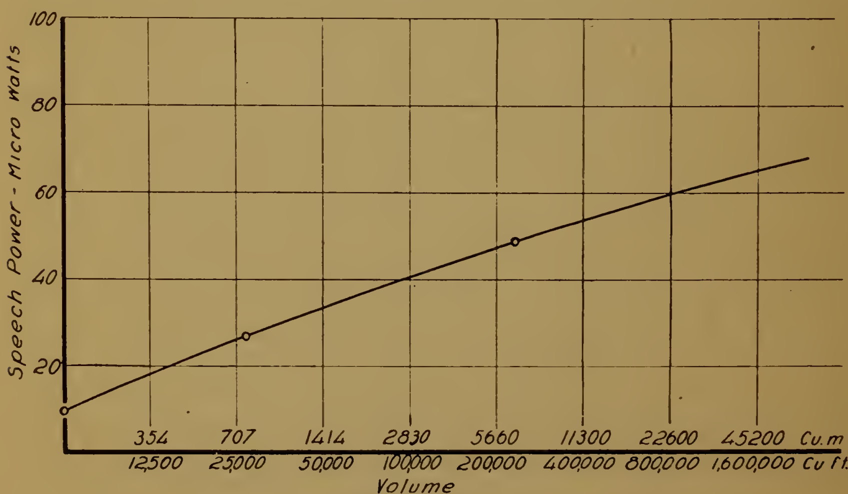

FIGURE 1.

Curve showing the probable speech power of the average speaker in auditoriums of different sizes.

average loudness which this acoustic power would produce in rooms of different sizes would depend upon the total amount of absorption in the rooms, since the average intensity of a sound in a room is inversely proportional to the total amount of absorption in the room.

The curve in *Fig. 2* shows the average loudness of speech of

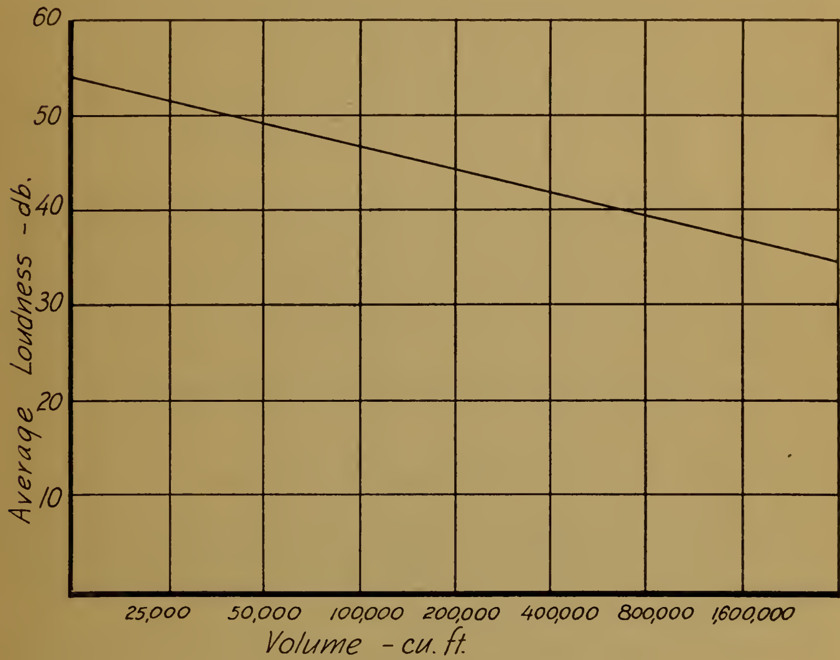

FIGURE 2.

Curve showing the probable loudness, in db, of the average speaker in rooms of different sizes, all having a time of reverberation of 1.25 seconds.

the average speaker in rooms of different sizes all having the same time of reverberation, namely 1.25 seconds. By referring to the dotted line curve in *Fig. 3*, which shows Fletcher's data for speech articulation at different loudness levels of speech, it will be observed that the average loudness of speech in large auditoriums, namely, 45 db. or less, is at a critically low level, so that the slightest interference from noise, or the slightest downward modulation of the voice will make hearing conditions unsatisfactory.

The early Greeks were fully aware of this inadequacy in the loudness of speaker's voices, and attempted to compensate for it, especially in the larger theatres, by two different devices. The actors on the stage wore huge masks which not only exaggerated facial expressions so that they could be seen from the

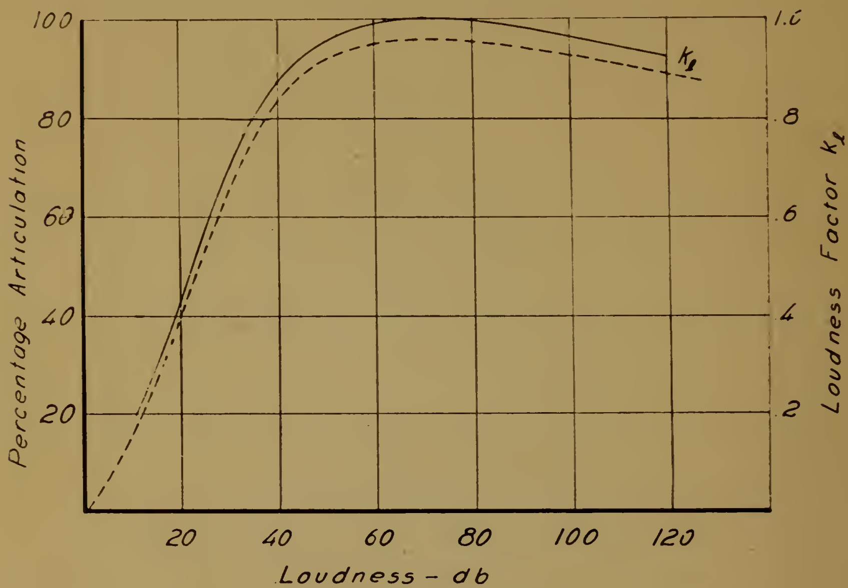

FIGURE 3.

Curve showing the effect of loudness upon the reception of speech (taken from Fletcher's data). The dotted curve gives the percentage articulation at different loudness levels. The solid line curve gives the loudness reduction factor k_1.

most distant seats, but also served to enhance the loudness of the voice by reason of the shapes of the masks which incorporated the principle of the megaphone. In addition, we are informed in the writings of Aristoxenus, a large number of bronze vessels, fashioned into resonators, were distributed in regularly spaced niches throughout the theatre. In large theatres there were three horizontal ranges of resonators at equally spaced vertical levels, with twelve resonators in each range. These resonators were all carefully tuned to resonate to the various notes of musical systems, for the purpose of emphasizing the more important frequency components of speech and music. One range of resonators was tuned for the anharmonic, another for the chromatic, and the third for the diatonic system. The actual merit of these resonators for enhancing the loudness and pleasing qualities of speech and music is rather difficult to assess, but it is doubtful that they were of any real value. On the other hand, the combined mask and megaphone was of unquestioned value for augmenting the loudness of the voice—at the same time, however, distorting the natural quality of the voice.

The use of these two devices—the megaphone and the resonator—most clearly indicates that in their open air theatres the Greeks were handicapped by the same difficulty that was revealed by the recent investigation of the loudness of speech in auditoriums; namely, that the natural, unaided voice does not provide an adequate supply of speech energy for good hearing in large auditoriums.

From the dotted line curve in *Fig. 3* it is possible to calculate the value of k_1, which will be useful in connection with equation 1. K_1 is taken as unity at a loudness level of 70 db and the value of k_1 at any other loudness level is obtained by taking the ratio of the percentage articulation at that loudness level to the percentage articulation at a loudness of 70 db. The solid line curve in *Fig. 3* gives the values of k_1 at different loudness levels.

(c) *Effect of Reverberation upon the Reception of Speech in Auditoriums.* We shall next consider the interfering effect of reverberation upon the hearing of speech in auditoriums. It would be expected, and experience bears out this expectation, that hearing conditions would be very unsatisfactory in reverberant rooms, owing to the overlapping and confusing of the separate syllables and words of articulated speech. The curve in *Fig. 4* shows how the speech articulation depends upon the time of reverberation, measured at a frequency of 512 d. v., in a group of auditoriums having about the same shape and volume (200,000 to 300,000 cubic feet) but different times of reverberation. The small circles in *Fig. 4* show the observed value of percentage articulation for the corresponding measured times of reverberation in the auditoriums investigated. The lower curve is drawn to represent the most probable fit with the observed data. It will be noted that, approximately, the articulation decreases six per cent for each additional second of reverberation.

The lower curve in *Fig. 4*, which represents the mean result of the experimental determinations, was not obtained for a constant loudness level of speech, because the loudness is de-

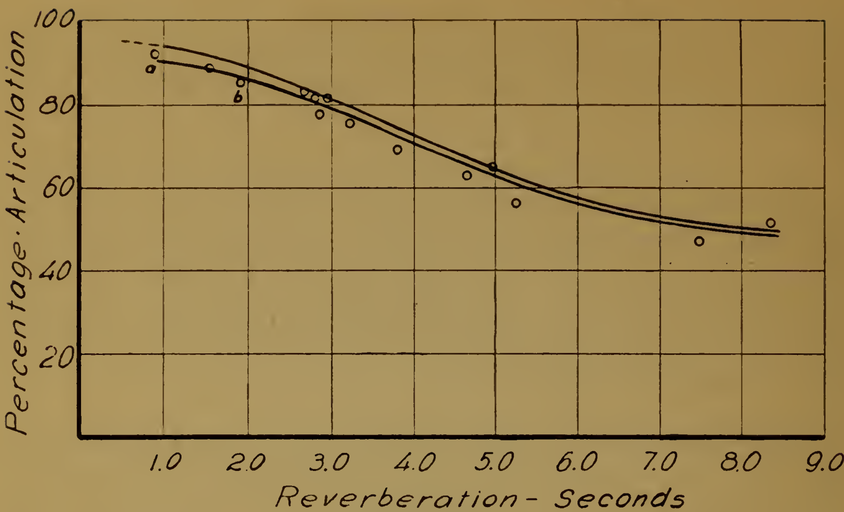

FIGURE 4.

Curves showing the interfering effect of reverberation upon the hearing of speech. The lower curve represents the most probable fit with the observed data. The upper curve has been corrected for loudness, and corresponds to a loudness of 70 db.

pendent upon the amount of absorption in the room. Assuming the power of the speaker's voice to remain constant,[1] the resulting intensity of the speech would be almost inversely proportional to the total amount of absorption in the auditoriums, or directly proportional to the time of reverberation. It was found experimentally that the average loudness of the speakers' voices used in these tests, in an auditorium having a volume of 8,440 cubic meters (300,000 cubic feet) and a time of reverberation of 1.50 seconds, was about 48 db. Using this datum, and the loudness-articulation data given in *Fig. 3*, it is possible to correct the lower curve in *Fig. 4* for variation of loudness. The upper curve in *Fig. 4* was obtained by applying such a correction so as to give the percentage articulation for a uniform loudness level of 70 db, which is the loudness level for optimal hearing. This curve has been extrapolated to a time of reverberation of .50 second, as indicated by the dotted portion of the curve. Such an extrapolation is warranted by articu-

[1]*This assumption seems more plausible than the alternative one that the speaker maintains a constant loudness level. It seems likely, however, that neither assumption is correct. A speaker generally attempts to raise his voice to the loudness level required for satisfactory hearing, but is limited by the physical characteristics of his speech apparatus.*

lation tests the writer has conducted in a small room in which the percentage articulation increased as the time of reverberation was reduced from 1.0 to .60 seconds.

It is now possible, from the upper curve in *Fig. 4*, to derive k_r, the reduction factor owing to reverberation, for times of reverberation between .5 and 8.0 seconds. The value of k_r is taken as unity for a time of reverberation of .5 second. The value of k_r for any other time of reverberation is the ratio of the articulation at that time to the articulation for a time of .5 second. The curve in *Fig. 5* gives the value of k_r, obtained in

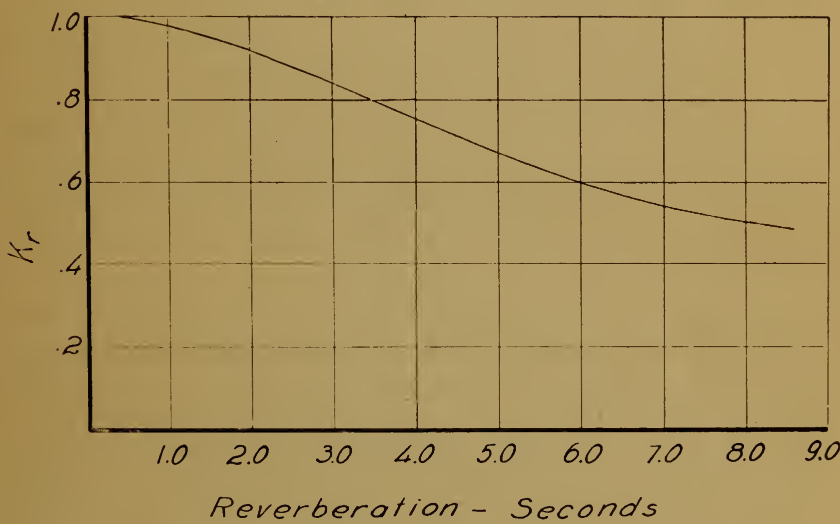

FIGURE 5.

Curve giving the reverberation reduction factor k_r for different times of reverberation.

this manner, for different times of reverberation. It will be noted that k_r decreases almost uniformly as the time of reverberation increases from 1.0 to 6.0 seconds. Above 6.0 seconds the rate of decrease of k_r appears to be less rapid.

The deviations of the observed points from the smooth curve in *Fig. 4* can be accounted for by such factors as the shape of the rooms, the variation in reverberation for tones of different pitch, and the distribution of absorptive materials in the rooms. Time will not permit us to enter into a discussion of these factors, although it may be stated that these various factors do not seem to produce a very marked effect upon articulation. In general it may be stated that the reverberation should be nearly uniform for tones of all pitch, and that the greater part of the absorptive material should be located in the neighborhood of the listeners rather than in the neighborhood of the speaker.

Both of these features just mentioned — the variation of reverberation with pitch and the distribution of absorptive material in the auditorium — will have an effect upon the reduction factor k_r. However, it is not probable that either of these features has a very significant effect upon the "percentage speech articulation" in an auditorium. It is probable therefore that, for a first approximation, the value of the time of reverberation for a tone of 512 d. v., as is commonly employed in current practice, can be used for determining, by means of *Fig. 4,* the appropriate value of k_r for any auditorium. The two features of reverberation under discussion are of unquestioned value in auditorium design, but their most important significance is in relation to the preservation of naturalness of speech and music rather than the improvement of speech articulation.

(d) *Effect of Noise upon the Reception of Speech in Auditoriums.* The interfering effect of noise upon the hearing of speech was considered in the preceding lecture. The principal results of the effect of noise upon hearing is indicated by the curve in *Fig. 6.* It will be noted that the articulation decreases almost uniformly as the loudest of the noise increases. Further, it will be seen that even a slight noise produces an appreciable interference. The complete absence of noise is thus seen to be an important factor for ideal hearing.

The curve in *Fig. 7* is derived from the curve in *Fig. 6.* It gives the value of k_n for different loudness levels of noise. The loudness of the noise is here represented by the ratio of the noise, in db, to that of the speech, also in db. Thus, when the noise is at the same loudness level as the speech, the abscissa in *Fig. 8* is 1.0. The value of k_n for no noise is taken as unity, and all other values of k_n are obtained by taking the ratio of the ordinate (in *Fig. 6*) for the loudness level in question to the ordinate for zero noise. This method of determining k_n is not strictly rigorous, but it gives a close approximation which is sufficiently accurate for practical problems in auditorium acoustics.

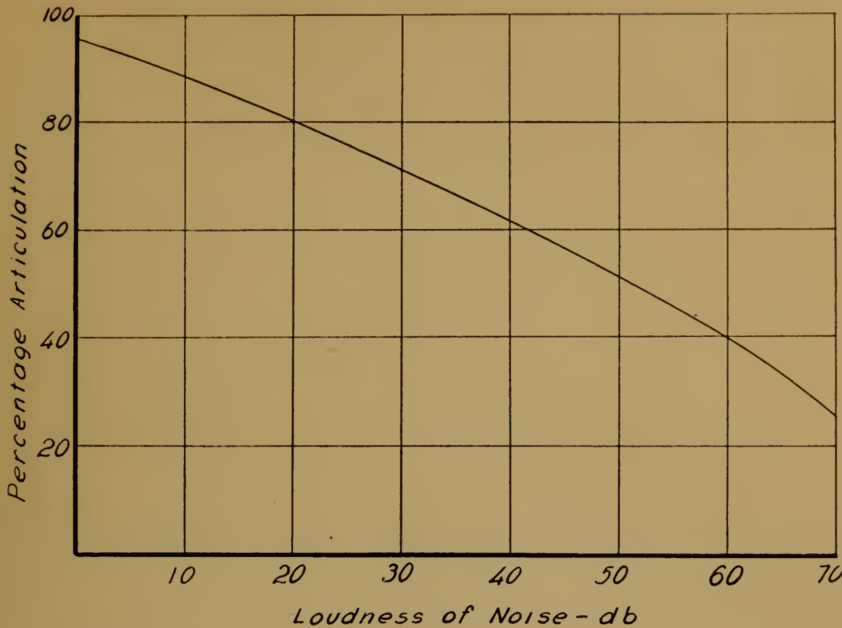

FIGURE 6.

Curve showing the interfering effect of noise upon the hearing of speech.

The manner of using this curve would be as follows: First determine, by measurement if necessary, the average loudness of the noise in the auditorium. Take the ratio of this loudness level, in db, to the probable loudness level of the speech, in db, and read off from the curve in *Fig. 7* the appropriate value of k_n. Thus, if it is found that the average noise level in an auditorium is 10 db and the average speech is 50 db, the value of k_n would be .925. The average noise prevalent in typical auditoriums is rarely lower than 5 db, and may sometimes be as high as 20 to 25 db.

(e) *Effect of Shape of Auditorium upon Speech Reception.* No quantitative tests have yet been conducted to determine the effect of shape upon the hearing of speech. There is undoubtedly some benefit to be gained from suitably located wall and ceiling surfaces near the speaker or the source of the sound, but more data are required to determine the exact benefit derived from such design. In general, it may be stated that it is advantageous to have good reflecting surfaces located near the source of the sound, so arranged as to reenforce the sound directed to the more remote parts of the room. A number of speech articulation tests have shown that the use of such reflecting surfaces behind a speaker are of definite merit, increasing the articulation in large auditoriums as much as three or four per cent.

FIGURE 7.

Curve showing how the noise reduction factor k_n depends upon the loudness of noise. The abscissa gives the ratio of the noise loudness to the speech loudness, where both are expressed in db.

The influence of the shape of an enclosure upon speech reception requires further quantitative investigation. In the auditorium of conventional rectangular shape, it is probable that the k_s (as used in equation (1)) does not differ appreciably from unity. In very large auditoriums, especially with curved surfaces, it is probable that k_s may be reduced to a value as low as .90. It is possible that in small rooms, or in auditoriums designed with properly shaped and located reflecting surfaces, k_s may reach a value as high as 1.05. For practical guidance in the design of auditoriums, it probably is advisable to assign a value of 1.0 to k_s, unless the shape of the auditorium is of peculiar design.

(f) *Combined Effects of Loudness and Reverberation upon the Reception of Speech in Auditoriums.* In the earlier sections of this paper the effects of loudness and reverberation upon speech reception were considered separately. It is obvious that as the time of reverberation in an auditorium is reduced, the average loudness of speech, assuming a constant power rate for the speaker, will be reduced correspondingly. This suggests that there may be an optimal time of reverberation for speech in an auditorium. This would occur when a further reduction in the reverberation would concurrently reduce the loudness to the extent that the impairment occasioned by the diminished loudness would just compensate for the improvement occasioned by the reduction of the reverberation. The manner in which this occurs is indicated by the series of curves which are plotted in *Fig. 8.* These curves give the calculated values of the percentage articulation in auditoriums of different sizes and times of reverberation, for the probable average loudness of speech of

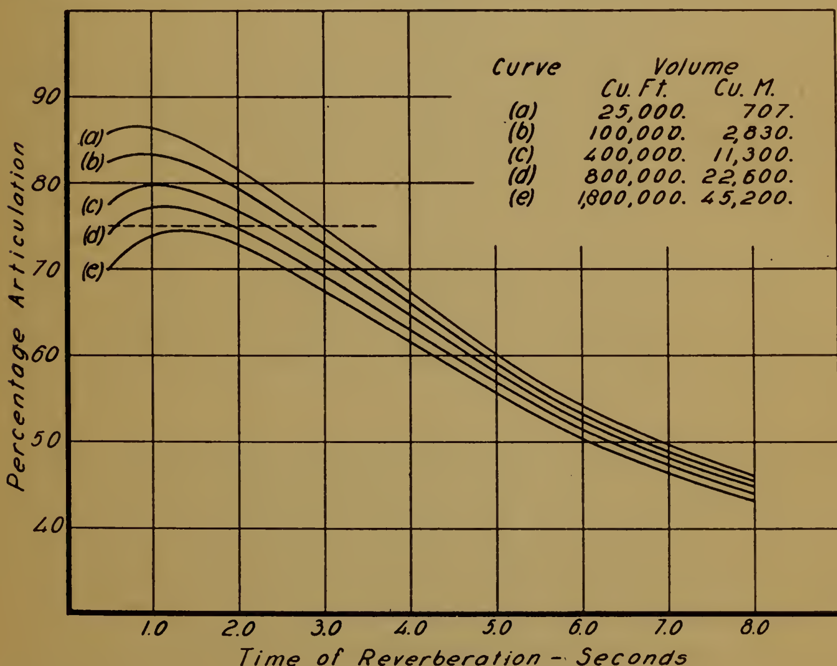

FIGURE 8.

Group of curves giving the probable percentage articulation in auditoriums of different sizes and with different times of reverberation. These curves indicate that there is an optimal time of reverberation for the hearing of speech in an auditorium of a certain size.

the average speaker, based upon the measurements outlined in this lecture. The average speech-power of the average speaker in auditoriums of different sizes is obtained from the curve in *Fig. 1.* Having determined, from *Fig. 1,* the probable speech-power of the average speaker in a room of a certain size, and assuming that the speaker maintains this power output for different times of reverberation, it is possible to calculate the resulting loudness in an auditorium of any size or time of reverberation. A typical set of calculations for an auditorium is given in Table I. The values of k_l and k_r are determined from

TABLE I.

Volume of auditorium = 11,330 cubic meters meters (400,000 cubic feet).

Average speech-power (from *Fig. 9*) = 54 microwatts.

Time of Reverberation	*Average Speech Intensity*	*Average Loudness in db*	k_l	k_r	$k_l k_r$
.50	.665 x 10^4	38.2	.850	1.00	.850
.75	1.00	40.0	.874	.993	.868
1.00	1.33	41.2	.885	.982	.870
1.25	1.66	42.2	.894	.967	.865
1.50	2.00	43.0	.900	.953	.858
2.00	2.66	44.3	.910	.924	.840
3.00	4.0	46.0	.925	.837	.775
4.00	5.3	47.3	.936	.752	.704
6.00	8.0	49.0	.950	.600	.750
8.00	10.6	50.3	.595	.510	.489

the curves in *Figs. 3* and *5,* respectively. It is assumed that the auditoriums are of the typical rectangular shape, so that k_s=1.0. It also is assumed that the rooms are relatively free from disturbing noise, so that the residual noise is only one-tenth as loud as the speech, and therefore k_n will be .96. Equation (1) then becomes:

$$\text{Percentage Articulation} = .922\, k_l\, k_r.$$

The ordinates of the curves in *Fig. 8* were calculated by the use of this equation and a series of tables like Table I.

It is obvious that, for an auditorium of a certain size, the optimal time of reverberation will be the time for which the product k_1 k_r, or the percentage articulation, will be a maximum. Thus the maximal values of the ordinates in the group of curves in *Fig. 8* indicate the optimal times of reverberation in auditoriums of different sizes, for speech of about the average loudness that would be commonly used.

The entire series of curves shows very clearly how the reception of speech depends upon the size and time of reverberation of an auditorium. As would be expected, the optimal time of reverberation for speech reception in a small room is as short as .75 seconds. In a very small room the loudness is adequate and therefore speech will be heard more clearly and distinctly the nearer the reverberation approaches zero. In large auditoriums a somewhat longer time is advantageous because it promotes loudness. It will be noted that the peaks of the curves in *Fig. 8* are rather broad and flat. This would seem to indicate that there is a considerable allowable variation in the time of reverberation from the optimal time, without appreciable sacrifice in hearing quality. In the design of auditoriums, therefore, it is desirable to so choose the absorptive treatment of the auditorium that the absorption furnished by different sized audiences will make the time of reverberation vary between the limits which determine the approximately flat portion of the curve.

Another factor must also be considered, namely, that the optimal time of reverberation for music is somewhat longer than for speech, and therefore it would be desirable to compromise between the requirements for speech and for music, especially in auditoriums which are to be used both for speech and music.

The optimal time of reverberation for auditoriums has been determined by Watson, Lifschitz, and others. These investigators have arrived at the optimal time primarily by calculating or measuring the time of reverberation in auditoriums which are pronounced good by competent critics. Lifschitz has derived a semi-empirical formula for calculating the optimal times of reverberation for auditoriums of different sizes. This formula yields results which are in fair agreement with Watson's results and with currently accepted optimal times of reverberation. The top curve in *Fig. 9* shows the values of the optimal time of reverberation as given by Lifschitz. Although Lifschitz states that his results apply both to speech and music, it is probable that they apply more particularly to music, since the results are based upon the judgments of listeners who regard loudness,

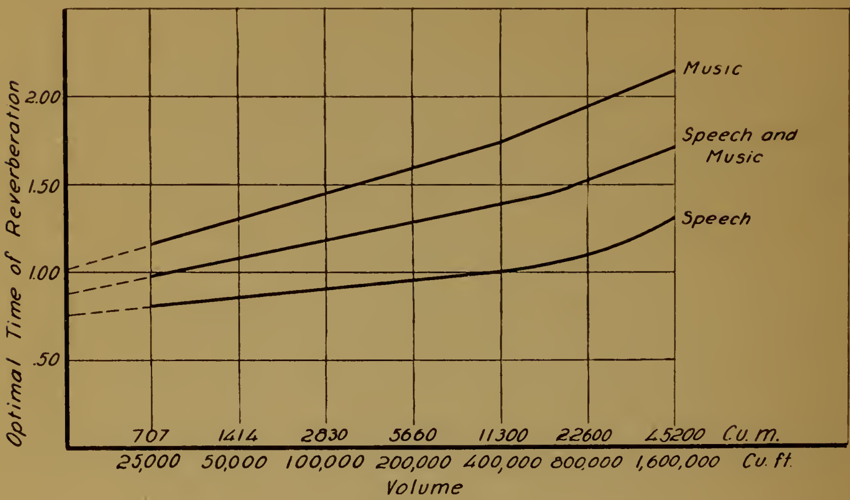

FIGURE 9.

Curves showing the optimal time of reverberation for auditoriums of different sizes. The upper curve is taken from the data of Watson and Lifschitz. The lower curve, for speech, is obtained from the maxima in Fig. 8. The middle curve is the arithmetical mean of the upper and lower curves, and represents a reasonable choice for both speech and music.

resonance, euphony and other qualities as determining factors. The lowest curve in *Fig. 9* shows the optimal time of reverberation for speech, based upon the maximal values of the curves in *Fig. 8.* It would seem that the bottom and top curves in *Fig. 9* give the most trustworthy available data for determining the optimal time of reverberation in auditoriums for either speech or music, where no provision is made for amplifying the power of the voice. If an auditorium is to be used for both speech and music, as is usually the case, it would seem advisable to use the mean value of the two curves. The middle curve is such a mean value curve, and thus gives the optimal time of reverberation for both speech and music.

The importance of the loudness of speech in a large auditorium is strikingly shown by the curves in *Fig. 10.* These curves have been calculated to show especially how the loudness of speech affects the hearing intelligibility in an auditorium having a volume of 11,300 cubic meters (400,000 cubic feet).

The curve marked (f) is for the weakest voice of the fourteen speakers used in this investigation. It will be seen that the articulation for such a speaker, even under the most favorable listening conditions in this auditorium, does not exceed seventy

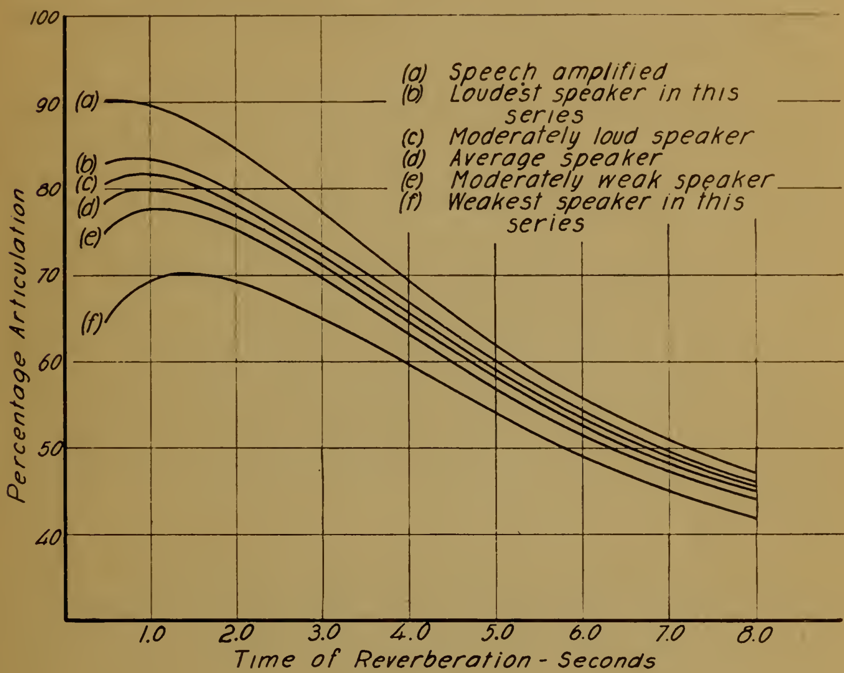

FIGURE 10.

Group of curves showing how the loudness of a speaker's voice effects the hearing of speech in auditoriums. These curves are for an auditorium having a volume of 400,000 cubic feet. The loudness of a speaker's voice is seen to be an important factor.

per cent. On the other hand, the curve marked (b) is for the loudest speaker in this series. The curve marked (e) is for the average of the four weakest speakers, and the curve marked (c) is for the average of the four loudest speakers tested in the large auditorium. The curve marked (d) is for the average of the eight speakers. It will be noticed that the louder speakers are heard very much better than the weaker ones—the optimal articulation for the loudest speaker is 83.5 per cent as compared with seventy per cent for the weakest one. This difference is quite significant inasmuch as an articulation of seventy-five per cent is required for satisfactory hearing.

It will be noted further, by referring to the curves in *Fig. 10*, that the optimal time of reverberation is different for different speakers even in the same auditorium, varying from about .85 second for the loudest speaker to 1.40 seconds for the weakest speaker. However, a time of reverberation of about 1.00 to 1.25 seconds will quite satisfactorily approximate the optimal reverberation for all speakers.

Curve (a) in *Fig. 10* has been calculated upon the assumption that the speech has been amplified, without distortion, to an energy level corresponding to a loudness of 60 db in this same auditorium when the time of reverberation is 1.0 second. The advantage of such distortionless amplification of speech is clearly indicated. Thus, with a time of reverberation of less than 1.0 second, the articulation is ninety per cent, which could be regarded as practically perfect for the hearing of speech. These calculations seem to indicate that suitable amplifiers (public address systems) are imperatively needed in large auditoriums. In addition, such amplifiers are also beneficial in smaller auditoriums, especially if the auditorium is beset with disturbing noise.

At a loudness level of 60 db there is no necessity of reverberation for the usual purpose of enhancing the loudness. In fact, the reverberation should be kept as low as is consistent with other considerations, such as maintaining sufficient brilliance and resonance in the room to meet the requirements for music. Curve (a) in *Fig. 10* indicates that the time of reverberation should not exceed 1.0 second for speech. Even for music, there seem to be no physical factors which would warrant a time of reverberation much in excess of 1.0 second (which is about the optimal reverberation for speech and music in a small room) if the loudness be maintained at about 60 db.

The present public address systems or the reproducing equipment in motion picture theatres ordinarily introduce a certain amount of distortion because of the limitations of the electrical and acoustical equipment used, and therefore a distortion factor k_d should be introduced in equation (1) when such amplifiers are used. In a properly designed public address system the value of k_d probably will be no less than .95. This point, however, requires further investigation.

Referring again to *Fig. 10,* and recalling that curve (a) was based upon distortionless amplification, it will be noted that if the amplifier introduces considerable distortion, the amplifier may be a hindrance rather than an aid to better hearing. Thus if the distortion factor k_d be less than .90, the added distortion will more than offset the advantage gained from increased loudness for all speakers except those with weak voices. It is important therefore that public address systems for auditoriums or reproducing equipment in motion picture theatres be of the high-quality type.

The curves in *Fig. 8* are of considerable value in placing a quantitative estimate on the acoustic merit of different auditoriums. They also indicate the limits of size and reverberation which can be tolerated if the percentage articulation is to be maintained at a satisfactory level. Experience has shown that if the average articulation in an auditorium be seventy-five per cent or more, the hearing conditions are regarded as satisfactory. It is possible to understand speech when the articulation is as low as sixty-five per cent, but it requires normal acuity of hearing and strained attention. If it be desired to keep the articulation above seventy-five per cent, and it seems to the writer that seventy-five per cent should be regarded as the admissible minimum, the size and time of reverberation of the auditorium are limited to values above the broken horizontal line in *Fig. 8.* Thus, it would seem advisable to regard about 800,000 cubic feet (22,600 cubic meters) as the upper limit to the size of an auditorium which is to be used for speaking, unless some amplifying equipment be installed for increasing the loudness. It should be borne in mind that this limitation is based upon the requirements for the average speaker. For speakers with moderately weak voices (see *Fig. 10),* the size should not exceed 400,000 cubic feet (11,330 cubic meters) ; and for speakers with very weak voices, the size should not exceed 100,000 cubic feet (2,839 cubic meters).

The admissible limits of the time of reverberation, in order that the speech articulation be above seventy-five per cent, are also indicated plainly in *Fig. 8.* Thus, in an auditorium having a volume of 400,000 cubic feet, the time of reverberation should not exceed 2.4 seconds. The 2.4 seconds should be regarded as the upper admissible limit for the time of reverberation in such an auditorium when it is used with the smallest probable audience it is to accommodate. It is good practice to design an auditorium such that this upper admissible reverberation is obtained with no audience present, and that the auditorium have the optimal time of reverberation with the most probable sized audience present.

The foregoing discussion will make it appear obvious that we have expected altogether too much from theatre and other auditoriums, where no provision is made for the amplification of sound. In a large auditorium, the loudness of a speaker's voice is at a critically low level, so that the slightest disturbance from noise, reverberation, or interfering reflections will result in unsatisfactory hearing conditions. There is, therefore, an urgent need for increasing, in some way, the loudness level of the average speaker's voice. An improvement may be expected from proper voice culture, or from suitable reflecting surfaces near the speaker, but the principal improvement is to be expected from artificial amplification of speech, as by suitable sound amplifiers. The improvement of apparatus for the reproduction and amplification of sound is progressing at a gratifying rate, and we may confidently anticipate that present and future developments in this art will make a most beneficial contribution to the problem of good hearing in large auditoriums.

It will be noted, because of the inadequate loudness of unamplified speech, that the talking picture enjoys a most significant advantage over the legitimate stage, particularly in theatres seating more than 1,000 persons. It is highly important, however, that the recording and reproducing equipment be so free from distortion that the advantage resulting from the increased loudness of the amplified sound is not overcome by the distortion introduced in the recording and reproducing processes. If high-quality equipment and technique be employed throughout all of the processes of recording and reproducing, the reproduced sound in the theatre should provide ideal hearing conditions. It is not necessary to have an excess of reverberation to promote loudness. And for this reason the optimal time of reverberation in a "talkie" theatre is considerably lower than it is for the legitimate theatre. This makes for better quality of both reproduced speech and music.

3. *The Control of Reverberation.* In the foregoing discussion it is shown that the proper control of reverberation in an enclosure is a paramount factor in the securing of optimal acoustic conditions. It is appropriate therefore that we outline the method of calculating the reverberation characteristics of a closed or partially closed space.

The simplest and the most useful equation for calculating the time of reverberation in an enclosed space is the following:

$$t = \frac{kV}{a} \qquad (2)$$

t represents the time of reverberation in seconds.

V represents the volume of the enclosed space in cubic feet.

k is a constant, equal to .05 for simple rectangular spaces, and varying between .04 and .05 for more irregular spaces.

a is the total absorption in the enclosed space.

a is given by the relation $a = \alpha_1 s_1 + \alpha_2 s_2 + \alpha_3 s_3 + \ldots$, where $s_1, s_2, s_3, \ldots$ represent the areas of the different materials bounding the enclosure or materials within the enclosure, and $\alpha_1, \alpha_2, \alpha_3, \ldots$ are the corresponding coefficients of sound absorption of the different materials.

In general it is necessary to calculate the reverberation at several representative frequencies, say 128 d. v., 512 d. v. and 2048 d. v., since the coefficients of absorption are not the same for all frequencies. In order to illustrate the use of equation (2), suppose we calculate the time of reverberation for a tone of 512 d. v. in a sound stage 80′ x 100′ x 35′. Suppose for the sake of simplicity that the ceiling is level, and that the entire walls and ceiling are treated with a wool blanket or a wool fill 4″ thick. The floor is soft wood. No sets or other equipment are in the stage. The volume of the stage is 280,000 cubic feet, the area of the floor or ceiling is 8,000 square feet, and the area of the walls is 12,600 square feet. The coefficient of absorption for the wool is about .60 and the coefficient for the wood floor is .06. Therefore the total absorption "a" in the room is $20{,}600 \times .60 + 8{,}000 \times .06 = 12{,}360 + 480 = 12{,}840$ units. The value of "k" for this stage is about .049. Hence, equation (2) becomes:

$$t = \frac{.049 \times 280{,}000}{12{,}840} = 1.18 \text{ seconds,}$$

that is, the time of reverberation for a tone of 512 d. v. is 1.18 seconds. Actual measurements of the time of reverberation in such a stage as the one we have here considered are in good agreement with this calculated time of 1.18 seconds. The usual sets and other equipment in the stage ordinarily will reduce the reverberation to slightly less than one second, a condition which experience has shown to be satisfactory, especially for the recording of speech.

The above calculations of reverberation have been limited to a frequency of 512 d. v. It is of course necessary to calculate and control the reverberation at other frequencies. If the reverberation be calculated at 128 d. v., 512 d. v., and 2048 d. v. it will be possible to determine the type of acoustic treatment which will give the best acoustic conditions. In general, the reverberation should be nearly uniform at all frequencies, with slightly more reverberation for the low frequencies than for the high frequencies. There are two reasons which suggest this type of reverberation characteristics for a room: (1) the low frequency components of speech and music are not so loud, judged by the ear, as the high frequency components, and therefore if all frequency components are to die away at the same rate and reach inaudibility at the same time, the time of reverberation should be somewhat longer for the low frequencies than it is for the high frequencies; (2) people are accustomed to hearing speech and music in rooms treated with materials which make the room more reverberant for the low frequencies than for the high frequencies. An audience, for example, is about two times more absorptive for the high frequency components than it is for the low frequency components. In general, the reverberation will be highly satisfactory if the room has a time of reverberation at 128 d. v. about fifty per cent in excess of the time of reverberation at 512 d. v. This subject, however, requires further experimentation in order to determine just what is the best type of absorptive material for the control of sound in interiors.

It is good practice to have a sound stage very dead acoustically, that is, the reverberation should be reduced to somewhat less than one second. The desired acoustic effects can then be obtained by the proper design of the sets. For conversation the set should be relatively dead, whereas for music it should be more brilliant. Again, if it is a church scene, the set should be reverberant, whereas if it is a living room set it should be rather dead. This whole subject is yet on an empirical basis, but carefully planned experiments should be carried out in order to place it upon a precise scientific basis.

The shape of, and manner of enclosing, the set are questions which also require further investigation. However, it may be said that the set should be of such a shape as will provide a uniform flow of sound energy to the microphone from all positions from which speaking will occur. In general, fairly good reflecting surfaces behind and surrounding the scene of action, and absorptive materials in the neighborhood of the microphone will provide the best arrangement. That is, the sound should be generated in a somewhat brilliant space and recorded in a relatively dead space. If the set is relatively open, the acoustic conditions resemble open air conditions, where the intensity of sound dies away inversely as the square of the distance from the source. In an enclosed space, on the other hand, owing to the many reflections from the surrounding walls, the sound energy does not die away so rapidly at increasing distances from the source. In a small room for example the intensity of sound energy is relatively free from dependence upon the distance from the source. The recording of sound in such a room allows a much greater freedom of motion on the part of the actor. The set should be designed in such a way as to be free from the defects of resonance or excessive reverberation. The reverberation characteristics of a set often can and should be calculated in advance of construction. This will often help to determine what materials will be suitable for the construction of the set. More information is needed regarding the acoustic properties of the materials which are available for set construction. The reverberation and resonance properties of these materials especially should be known.

4. *The Insulation of Sound.* The insulation of sound is perhaps one of the most talked of subjects in connection with

the acoustic design of sound stages. In the early stages of talking pictures, it was felt that the sound-proofing of the stage was about the only factor which required consideration. It is, to be sure, an important factor, although no more important than the problems of stage and set reverberation. Experience and measurements have indicated approximately the following:

(1) If the stage has an insulation value of 50 db at 512 d. v., which means that a tone of this frequency will be reduced 50 db when it is transmitted through the stage, it will provide tolerable insulation for a single stage. If two or more stages of this type adjoin each other it may be necessary to shut down in one stage while recording in another.

(2) If the stage has an insulation value of 60 db at 512 d. v., it will be found to be fairly satisfactory under usual conditions. Outside noises such as the racing of a motor or the passing of a heavy truck, will be adequately insulated. In general, it will be possible to record in adjacent stages, except when there are very loud sounds in one stage, such as a large orchestra or very loud shouting.

(3) If the stage has an insulation value of 70 db at 512 d. v., it will be entirely satisfactory for all types of recordings which are now made in the studios. There will be no interference between adjacent stages, and it will not be necessary to stop recording in one stage while recording in another.

Two methods are in general use for the insulation of sound: (1) the use of heavy rigid walls and partitions; and (2), the use of multiple layers separated by air spaces. In the heavy rigid type of partition the insulation value is proportional to the logarithm of the mass of the wall per square foot of wall area. The insulation values provided by rigid walls, varying in mass from one pound per square foot to one hundred pounds per square foot, are given in the following table:

Mass per Square Foot of Wall Area	*Insulation Value in db*
1 pound	24
5 pounds	33
10 "	38
20 "	43
40 "	48
60 "	51
100 "	54

The values given in this table are for a frequency of 512 d. v. In general, the insulation is slightly less at 128 d. v. and slightly more at 2048 d. v. than the values given in this table.

For porous, flexible materials the insulation is almost proportional to the thickness of the material, and therefore for a given material the insulation value would be proportional to the weight of the material used per square foot of wall section. Often a combination of the dense, rigid partition and the porous, flexible material will provide the required amount of sound insulation. The use of multiple layers attains its highest insulation value when the separate layers are free from all connections or ties. That is, a stage inside of a stage with no connection between the two except through the earth will provide an insulation which is nearly equal to the sum of the insulations provided by the two structures. If the walls or ceilings of these two structures are connected in any way the over-all insulation becomes less than the sum of the insulations of the separate structures. In case the two structures are rigidly connected together they become essentially a single wall and the total insulation is almost proportional to the logarithm of the mass per square foot of wall area—the same as for a dense, rigid wall.

5. *The insulation of Vibration.* It is often necessary to provide large mountings in the recording room which will be free from mechanical vibrations. For example, the wax shaving machine is particularly sensitive to solid borne vibrations. Further, these solid borne vibrations are often communicated

from one stage to another through the solid members of the structure. The most feasible means of preventing the transmission of solid borne vibrations is to support the building or room or equipment which is to be insulated upon flexible supports. The problem is one which lends itself to quantitative formulation, which can be solved by methods analogous to electric circuit theory. From a practical standpoint, rubber and cork are among the best materials for providing such insulation. The room or object to be insulated should rest upon a flexible support, and the natural period of the object on its flexible support should be low in comparison with all frequencies which are to be insulated. In general, ordinary heat insulation cork loaded to about six or eight pounds per square inch or machinery insulation cork loaded to about twenty to forty pounds per square inch will provide effective insulation against audio frequency vibrations.

SOUND PERSONNEL AND ORGANIZATION

*Carl Dreher**

With the advent of sound in the motion picture industry, some peculiar problems of employment and organization arose. An intricate and highly evolved business had to assimilate, in the space of a year or two, a large body of technicians from another field, train them in its methods, and in turn modify its own technique to meet new and exacting requirements. The speed with which the amalgamation was accomplished speaks well for the adaptability of both the film group and the majority of the newcomers. The problems which arose, overshadowed at the time by questions of major technical and economic importance, are still of sufficient interest to justify some consideration in the present course, especially as their complete solution lies in the future.

Since the moving picture background is familiar to most readers of this paper, it is unnecessary to discuss it here. The history of sound recording and reproduction is in many respects analogous, with the addition of an important factor: the electrical technique based largely on the vacuum tube and its associated circuits. The early phonograph art resembled motion pictures in the fusion of esthetic and mechanical elements. In each case the artist has to reach the public through a machine. Early attempts to combine the two processes failed, largely because the sound reproducing elements were still too imperfect. In the meantime the radio art had started on its development. For a time, during the first two decades of the century, radio was purely a business of telegraph signalling without wires. The potentialities of the vacuum tube as an amplifier and generator of currents of almost any frequency promoted the spread of radio technique into the wire telephone art, the phonograph industry, and the amusement business.

**Director of the Sound Department, RKO Studios.*

These developments have a bearing on the sources of sound picture personnel. Many of the sound technicians now in the picture business began their careers as wireless operators or engineers. The early history of radio showed the usual characteristics of instability and financial turbulence of any new industry. The men who chose it for a career were, as a consequence, young, adventurous, and more adaptable than the average. When broadcasting became an adolescent member of the family of radio industries, a certain percentage of these men chose the path away from electrical communication into a business with theatrical elements and immediate contact with the amusement-seeking public. In the meantime technicians from the radio and telephone industries, finding positions in phonograph recording organizations when that field turned to electrical methods, likewise became available for work in sound pictures. As a third major source of supply, the laboratories of the electrical and telephone companies produced their quota of engineers who were more or less fitted for the special requirements of sound picture production. In addition to these groups, there were men already in the picture field who had qualifications for sound work.

IMPORTING PERSONNEL

This brings up the first of a number of arguable points. In the building up of an effective sound department, to what extent was it advisable to go outside of the motion picture industry for personnel? Had the adoption of sound been a gradual process, it might have been necessary to import personnel to the extent of only a half, say, of the total number of people required. Because competitive conditions, and the inherent nature of the business, required an extremely rapid consolidation, it is estimated that eighty percent of the sound men were taken from the outside. The majority of sound executives in Hollywood appear to feel that this ratio is somewhat high, and that the best results at the present juncture may be secured by mixing about two thirds of what may be loosely called radio personnel with one third film personnel. There are, however, extreme views on either side of this compromise. One prominent sound head expressed the opinion that the personnel of the department should be secured entirely from outside sources, such as engineering schools; telephone, radio, and electrical laboratories; broadcasting stations;

radio receiver factories; public address installations; phonograph recording studios, etc. Another executive recruited his entire sound personnel from the employees already on the lot, training them with the aid of engineers provided by the licensor of the recording equipment. He concedes that this course involved considerable delay in getting the department under way, but believes there will be compensations later. Since both of these companies are successfully producing sound pictures, the conclusion apparently is that a sound department, like most other enterprises, may be run on different theories, as long as there is some internal consistency in the carrying out of whatever scheme is selected, and certain general prerequisites of organization are not neglected.

We may now consider in some detail the organization of a sound department and the functions of the various employees, shown in the more or less typical schematic arrangement of *Fig. 1*. This is intended to apply to a lot which confines itself to recording on film, using mobile equipment which may be moved *physically* from one stage to another, so that all the apparatus is on or near the stage or location. This is in contradistinction to the system whereby the main amplifiers and the recording machines are centrally located and connected electrically to various pick-up points, movement from stage to stage, where required, being accomplished *electrically*. (See *Fig. 2*). Both systems are in extensive use and each presents certain advantages, but the organization of the sound department is somewhat affected by the choice of one or the other method.

PERSONALITY COUNTS

Another reservation with regard to the organization charts to be discussed is that any such scheme is a product of development, personalities, economic factors, and company policy, as much as a logical arrangement of men and functions. The greatest enemy of healthy business organization is the man who makes a fetish out of an organization diagram. Those who have learned this by experience will readily understand that any such scheme is subject to numerous modifications in practice.

Starting at the apex of *Fig. 1,* we have a *Director of Sound,* who may also be known by some such title as *Chief Recording Engineer.* He is essentially a department executive, in a position as much administrative as technical. His responsibilities

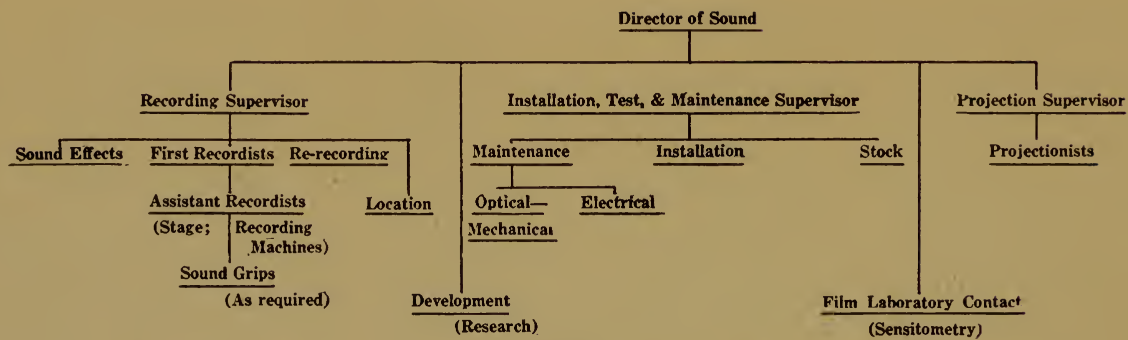

FIGURE 1

STUDIO USING PORTABLE EQUIPMENT; FILM RECORDING ONLY.

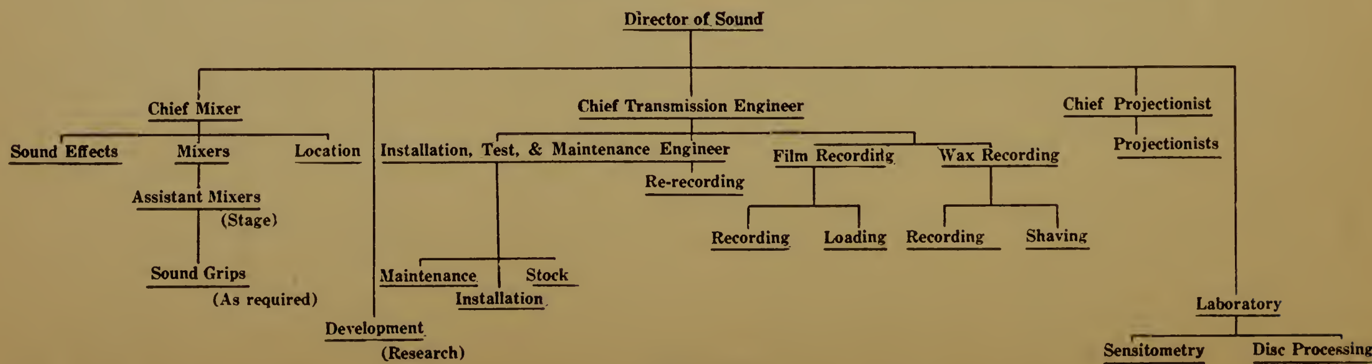

FIGURE 2

STUDIO USING CENTRALIZED INSTALLATION; FILM AND DISC RECORDING.

cover such functions as recording; installation, test, and maintenance of equipment; laboratory control in so far as sound track is involved; a certain amount of apparatus development work, the extent varying with different studios; and frequently projection. In one company the same technical executive directs both the camera and sound departments. The advantages of such a unification may bring about its wider application, unless it should prove too difficult to find men willing and able to tackle the problems of both picture and sound recording.

MUST MERIT CONFIDENCE

Generally the sound director is an engineer by origin, but the successful handling of his job calls for many qualities not always acquired in the course of an engineering career. He cannot judge the ultimate value of his product unless he has a critical appreciation of quality in speech and music. He must be able to translate technical verbiage into concise English, since most of his contacts are with other technical branches or with non-technical executives. At the same time he should be familiar with the nomenclature and at least the fundamentals of technique in the branches of the business allied with his: photography, cutting, etc. He should have a wide acquaintance among the technical men in his field, so that he will be in a position to add to his staff the best men the market affords at the price he can pay. He must meet the indispensable administrative requirement of being a good judge of human nature and meriting the confidence of his men. There is only one way to acquire and retain that confidence, which is the foundation of organization morale: subordinates must feel that, while the head of the department will exact work and progress on the part of the staff commensurate with the constantly rising standards of the art, he will also see to it that they get their share of the rewards of such progress, and that he will defend them resolutely against unjust attacks, to which a technician in a rapidly developing art is peculiarly exposed.

Recording is under the superintendence of a *Recording Supervisor,* whose subordinates carry on the actual work of transferring sound from air to film. The recording supervisor requires essentially the same qualifications as the director of recording, within the scope, at least, of operational problems. He must exercise careful judgment in assigning personnel to the particular associate producers, directors, and leading players with whom they will be able to get along best. The crew assigned to a given company usually consists of a *First Recordist** and two *Assistant Recordists,* one of whom is on the stage while the other operates the recording machine proper. *Fig. 3* shows the usual layout of the equipment and the positions of the personnel. The microphones are shown on the stage, whence the voice currents travel to the amplifier in a booth or sound truck, then to the recording machine immediately adjacent. If the machine is objectionably noisy, the booth may contain a partition separating the recorder proper from the amplifier and its associated monitoring speaker. The first recordist, who is in charge of the unit, is stationed in the room with the amplifier, the gain of which he adjusts himself. He also mixes the output of the microphones when several are used, and he has final responsibility for the placing of the transmitters. The two assistants are in continuous communication by telephone, with the first recordist on the line intermittently, or he may prefer to give his directions to the assistant directly, the latter then passing them on to the stage man. Where communication through intermediaries is unsatisfactory, the first recordist goes on the stage and contacts directly with the director or his assistants.

SOUND AND STORY

Another question on which opinions vary is the desirability of the sound man understanding something of story values, the technique of acting, and other elements of production somewhat remote from the transmission units and dynes per square centimeter which are naturally his first concern. One count in the blanket indictment brought against sound engineers by many picture people in the early struggles of adjustment, set forth that the sound technician was willing to sacrifice brilliant photography, vigorous action, and every other constituent of a good motion picture to get what he conceived to be good sound. Often enough the complaint was justified, as the early results show. On the other hand, one must learn to walk before one can run, and the utilization of natural distortion in recording, the introduction of "sound perspective," and the following of the action of a photo-

*The term *First Recordist* is intended to correspond to *First Cinematographer. Recordist,* while open to some objections, is used to differentiate the man from the machine, which is called a *recorder.*

play with moving microphones, were all devices either originated by engineers or developed through their cooperation.

It is clearly essential that the head of a sound department should be able to understand the literary and dramatic aspects

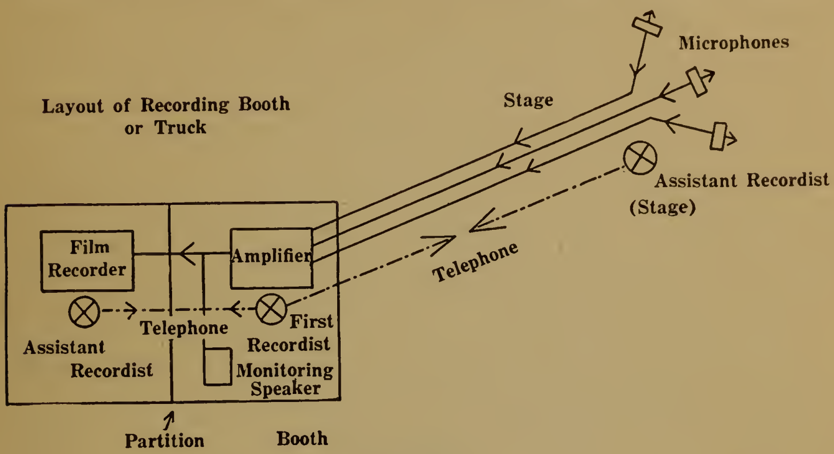

FIGURE 3

Typical layout of recording booth or truck in studio using portable equipment for recording on film.

of picture making, so he may help to create the devices necessary to produce the desired emotional effects in audiences. But should the "mixer," or head of a sound crew, possess this ability? Most of the sound executives interviewed thought such traits were a distinct asset, and this view happens to be the one favored by the present writer. One of the leading managers argued, on the contrary, that the business of the play and the merits of the plot were solely the affair of the director, and preferably the mixer's disposition should be such that he will be interested only in getting intelligible dialogue and good music and not overshooting the amplitude limits of the equipment. He did not want to run the risk of the sound man becoming what is known in the art as a "script-meddler." The fact that a dissenting opinion was expressed shows, even if time should prove it wrong, that final conclusions cannot yet be arrived at in the choosing and training of sound picture personnel.

STAGE PSYCHOLOGY

In addition to a good ear, one quality the "mixer" (the term is a misnomer in that he frequently uses only one microphone, and harmful psychologically by its tacit encouragement of excessive manipulation of the gain controls) must have, and that is imperturbability. Of all the elements of character required for the job, coolness in difficult situations is the *sine qua non.* Agitation, except on the part of actors and a few directors, cannot be tolerated on a stage, for the simple reason that there are so many things to be agitated about that a general demoralization would be the result if everyone yielded to panicky or irritable impulses. Furthermore, a show of apprehension or uncertainty results in a loss of confidence which, in the atmosphere of picture production, is extremely harmful. It may, for example, cause actors who play important roles to imagine that their voices will be poorly recorded, and that fear in itself may detract from their impersonations to such an extent as to seriously reduce the dramatic and box office value of the picture. Closely connected with this quality of calmness under tension is the power to make decisions quickly and without elaborate explanations. When the first recordist is asked whether a take is good for sound or not, he should be able to answer yes or no. If he is uncertain, the proper answer is no, with a compact statement of what he believes will improve the take from the viewpoint of sound. In this way production is accelerated and the best mental and emotional attitude maintained among the members of the company. Finally, the sound man who does his work on the stage must have a pleasant personality. A pleasing address is frequently as important as technical knowledge. Of course the sound men cannot expect to get by on amiability alone, but it helps immeasurably when combined with the other technical and personal qualities which are required in his work.

The assistant recordist on the stage, in addition to his function of maintaining communication with the recording booth, generally operates the microphone boom when it is necessary to follow the action. He therefore requires considerable training in practical acoustics.

Microphones are suspended as required by sound grips, who are under the direction of the stage recordist. The assistant recordist in the booth loads and unloads film and watches the machine for irregularities during operation.

Where both portable studio equipment and location sound trucks are in use, a separate crew may be assigned to the trucks, but it is probably more effective to train the personnel to handle both types of equipment, thus enabling the same crew to work through an entire picture, whether it is shot entirely in the studio or in the studio and on location. In some studios all the recording equipment is mounted on trucks and the problem of training personnel for two kinds of equipment does not arise.

WHO SHOULD RE-RECORD?

The production of sound effects may be left to a specialist under the direction of the recording supervisor, or reporting immediately to the director of sound. In either case the sound effects man works with the first recordists, either during the shooting of the pictures or during re-recording. Re-recording is another function which, under the organization system of *Fig. 1*, is one of the responsibilities of the recording supervisor. It is a moot point, however, whether the re-recording should be done by a specialist or by the first recordist who originally made the sound for the picture. The latter often tends to resent the idea that his work requires changes before it is released, while if the re-recording is placed entirely in the hands of a specialist, the director is put to the trouble of conveying his ideas on sound level and quality to this second technician. The best system is probably to assign re-recording to a specialist who knows the capabilities of his equipment and the best method of adapting the final sound version of the film for effective theatre projection, with consulting service by the original recordist, the cutter assigned to the picture, and the director or his deputy, the picture supervisor and the supervisor of recording having the final decision when disputes arise.

The functions of installation, test, and maintenance are largely self-explanatory and will not require extended treatment here. Whenever possible, it is well to unify these responsibilities in one engineer, although the actual work must be done by specialists. An amplifier maintenance expert, for example, usually is not skilled at stringing light valves, and *vice-versa,* but both functions are vital from the over-all standpoint of recording. It is impossible to record pictures successfuly on a large scale unless routine tests, daily frequency runs, etc., are attended to faithfully, and capable trouble-shooters are on hand when some unexpected difficulty arises in spite of preventive measures.

THEATRE CONTACTS NEEDED

Projection, although a dual function, with picture elements of as much importance as the sound, is in most studios under the control of the sound department. The reason is simply one of expediency. When sound invaded the industry, picture projection had reached a stage where no serious difficulties were encountered, whereas sound projection presented numerous problems of personnel training and addition of equipment. Projection as an uncertain factor in the judging of sound recording may entail a serious division of responsibility if it is assigned to another department, although here, as in many other instances, much depends on the individuals. Where the problem is not solved by handing over studio projection *in toto* to the sound department, at least the maintenance of the sound reproducing machinery is delegated to it. Some sound departments also employ one or more technicians as theatre contact men to check up on conditions of sound reproduction in the field. This is obviously a prudent measure, since too often infinite pains are taken by the producing staff (and an almost infinite amount of money spent) with everything that goes into the negative, after which all hands trust to luck in the presentation of the picture to the public. As far as quality of release prints is concerned, it is gratifying to note that the Academy of Motion Picture Arts and Sciences is taking appropriate action to remedy the present deficiencies.

Development and research are obviously topics of importance in an industry as wholly dependent as motion pictures on technological factors, which are still far from a state of perfection. In general, fundamental problems of sound recording and reproduction are best handled in the laboratories of the equipment manufacturing concerns, but many problems, such as camera-silencing, set construction, correction of acoustic defects by re-recording, etc., require work in the field.

Sensitometry, and the control of photographic elements in the developing and printing of sound tracks on film, are of obvious concern to the sound engineer, since the most carefully exposed sound negative may be ruined by poor processing in the laboratory, and, conversely, lack of correlation between the photochemical elements and exposure conditions may result in degradation of quality or even loss of takes. One or more photographic specialists are therefore found on the staff of every adequately organized sound department, and a routine of test strip preparation to indicate optimum conditions of development is carefuly maintained.

CENTRALIZED INSTALLATION

As shown in *Fig. 2,* recording organization is in general somewhat more elaborate where a central power, amplifier, and recording installation is used instead of portable units. The centralized scheme usually results in increased specialization. The *Chief Mixer,* corresponding to the *Recording Supervisor* of *Fig. 1,* does not have jurisdiction over the final step of engraving on wax or exposing film. These functions, instead, constitute part of the responsibility of a *Chief Transmission Engineer,* who is concerned with the operation of the plant, exclusive only of the stage, and its maintenance throughout. Alternatively, the mixers may also be under the control of the chief transmission engineer, who then becomes an assistant to the recording director in the immediate vertical line below the latter. With the addition of disc recording, also, various supplementary functions enter the organization picture, e.g., wax shaving, laboratory processing of discs, etc. The latter, added in *Fig. 2* as merely a single line, is of paramount importance in those companies which release principally on disc and have their own pressing plants. These would really require another organization chart for complete treatment, which need not be included, however, in a general paper.

TOO MANY APPLICANTS

Before closing the subject, I should like to invite attention to an economic phase of the sound problem which is of foremost interest to many people outside of the industry.

Any sound executive's mail reflects a great aspiration on the part of many radio and electrical technicians to get into the movies. This desire arises partly from the glamour of the business, partly from the publicity with which it is so richly endowed, and partly from the relatively high salaries which successful sound men command. Furthermore, there was an acute scarcity of sound men in Hollywood during the transition from silent to sound pictures, and the news of this El Dorado is still reverberating among the ambitious and the dissatisfied—unfortunately with a time lag of 1-2 years. As is usual in such cases, the supply has more than caught up with the demand, even during peaks of production. During periods of only moderate activity, as at the present writing (March, 1930), there are considerable numbers of qualified sound engineers out of work in the Hollywood district. The number of jobs is at best very limited. *Variety*, in its survey of motion picture studio employment, reported in its issue of January 8, 1930, gave the following figures for sound personnel in the Western Studios:

Company	No. Employees in Sound	Company	No. Employees in Sound
Warners	193	Columbia	22
Metro-Goldwyn-Mayer	147	Tiffany	15
Paramount	105	Tec-Art	12
Universal	100	Hal Roach	10
Fox	75	James Cruze	9
United Artists	44	Mack Sennett	4
Metropolitan	41	Educational	4
RKO	32	Larry Darmour	4
Pathé	32	Miscellaneous	71
First National	29		Total 949

While in some cases these figures have been increased since the tabulation, it is clear that there are only about 1000 sound jobs in Hollywood. This is surely nothing to write home about, especially as Los Angeles affords relatively few jobs in allied fields to the man waiting for a moving picture sound connection. It may be conceded that many of the men who are now knocking at the gates are just as good as those who are inside, but the ins are in, and the mortality among them is not sufficiently high to justify extravagant hopes on the part of the waiters in anterooms. Furthermore, the introduction of student engineering courses in some of the studios, the association of some of the producers with the electrical manufacturing companies, and the prior rights of eligible men in other departments of moving picture companies, further decrease the opportunities for immediate entrance for men whose experience has been confined to other fields. In short, sound must echo the warnings issued from time to time in the older branches of the industry against blind ventures in the direction of Hollywood, where neither the climate nor the scenery nor the presence of the national heroes and heroines can compensate for the lack of a personal income.

MOTION PICTURE SOUND RECORDING BY RCA PHOTOPHONE SYSTEM

*R. H. Townsend**

I have in my library a large volume that is yellow with age. The pages in this book are still firmly held together by a stiff sheep skin binding. On the pages are vertical lines of Chinese symbols. In spite of the fact that the symbols were made on these pages long before Guttenberg invented his printing press and used type, I have been told that the pages in this book are really printed. The book was given to me by a Chinese prince, a former schoolmate who knew that I was interested in sound. There is one passage which tells of a Chinese sovereign who spoke into a teakwood box and then dispatched this box by courier to a brother prince in a neighboring province. The recipient is described as placing his ear near to a hole in the box and turning a handle. This permitted him to hear the voice of his friend.

This episode was supposed to have happened about 4000 B. C. and constitutes, I believe, the first reference to sound recording. It is unfortunate that the Potentate of the Press or the Pen, or whatever was used in those earlier days, was not more prolific in the notes he kept so that we of the Twentieth Century, who think we are so very original, could have learned in detail how such a thing was possible. Because of his shortcomings, it became necessary for Thomas Edison almost 6000 years later to discover all over again that indentations on a piece of lead foil could be used to actuate a diaphragm and produce sound.

Most of us are inclined to think of sound recording as a comparatively recent development, but, as in the case of many other things, a careful survey of its antecedents shows that the ancients, too, knew quite a bit about some of our so-called modern inventions.

Even the application of sound recording to pictures is not so

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**Supervising Engineer RCA Photophone West Coast Studios*

recent and although the earlier experimenters were handicapped by lack of modern equipment, some of the ideas they advanced and worked on are being made use of in our present methods.

At the present time, there are two distinct types of sound recording. There is a type with which we have been familiar for several years and no doubt each of you has in his home a great many examples of it in the form of phonograph records. This type of recording is generally referred to as the disc or wax type. This latter term, in view of the present recording methods, is somewhat of a misnomer, because the material on which the original record is engraved is not wax at all, but an insoluble soap. Other Academy papers will describe in detail this method of recording and I will merely refer to it now as being a method whereby a sapphire stylus attached to the vibrating armature of a cutting head, cuts a logrithmic involute in the master blank. This disc is then graphited and electroplated with copper to obtain what is known as a master. This master is plated to produce a mother and the mother is plated to produce stampers. The stamper is then nickel faced and used in a hydraulic press to make impressions in a biscuit of a black compound known as record stock. This results in the record we all know—a record which may be, and usually is, a very accurate sound picture of the original.

The other type of recording is usually referred to as film recording and may be divided roughly into two general systems. One is known as variable density recording. Major exponents of this system are Western Electric Company and Fox Movietone Company. The other division is known as variable area recording. It was developed and is used by RCA Photophone. In the next few pages a brief discussion of the RCA Photophone system and apparatus will be presented.

Up to a certain point, the RCA system is essentially the same as the systems used by Western Electric Company and the Fox Movietone Company. The first unit in the system is a microphone which intercepts sound waves and converts them into electrical waves. In order that there be no loss, it is necessary for the shape of the electrical wave produced by a microphone to be the same as the sound wave which caused the diaphragm in the microphone to move.

In brief, the microphone consists of two metal plates. The diaphragm is one plate and behind this at a distance of

0″.0015 is the other plate. The diaphragm is made of duralumin rolled to a thickness of about 0″.0015 and stretched to a very high tension in a frame, not unlike the embroidery hoops our mothers used to use. The diaphragm is electrically insulated

FIGURE 1

Photophone Type R-3 Recorder threaded with film.

from the back plate and forms in reality a simple condenser, hence the name condenser microphone.

The action is quite as simple as its construction. A fairly high voltage, usually about 180 volts, is impressed across these two plates through a very high resistance. This resistance is usually from 20 to 50 million ohms. As the sound waves strike the diaphragm, it moves back and forth, causing a very slight change in capacity. This change in capacity makes itself evident as an alternating current flowing through the microphone and the resistance. Across this resistance is coupled the first tube of the amplifier, which takes this very tiny electrical signal and increases it to the degree necessary for operating various devices on the other end.

These amplifiers are so constructed that one may use almost any number of microphones and combine the output of these microphones into a single complex electrical wave which passes through the amplifier, increasing in strength at each stage. These amplifiers end in what is termed a power stage. This stage is so designated because, up to this point, we have been amplifying voltage and at this point we use that voltage to control vacuum tubes whose capacity in watts, the unit of power, is large enough to drive the mechanisms which do the work.

The output of this power stage is split into two channels. One channel consists of a monitoring circuit in which the electrical current is delivered to a dynamic cone and converted back into sound. If there were no losses anywhere in the system, it would be then possible for an operator listening to this loud speaker to hear exactly what is happening on a set or in the studio with approximately the same loudness as the original sounds. Unfortunately, however, each portion of the system so far described introduces various forms of distortion so that the sound one finally hears from the monitoring speaker is only approximately the quality of the original. These distortions are quite small, however. As a matter of fact, if it were possible to pour reproduced sound into a theatre or auditorium with the fidelity of the sound from a monitor speaker, I am sure motion picture audiences would feel much more kindly toward talking pictures.

Returning to the amplifier, we find that the rest of the power delivered is used to actuate the device which does the actual recording. Up to this point, all methods of recording are identical. From here on, each system makes use of a different recording device.

A side view of the RCA Photophone recorder mounted for operation is shown in *Fig. 1*.

In *Fig. 2* the adjustments for the optical system are shown in more detail.

The RCA system recorder is called a vibrator. It consists of a flat wire .0005″ thick and .005″ wide, stretched over two ivory bridges spaced 7/16 of an inch apart. This loop is put under tension by means of a spring attached to a tiny ivory pulley at the closed end of the loop. The ends of this wire, which are spaced 0″.01 apart, are attached to binding posts and connected to the output of the amplifier. At a point half way between the ivory bridges, there is a very tiny glass mirror cemented. This vibrator is then placed between the poles of a permanent magnet in such a way that the wires lie across the plane of the magnetic flux. You will notice that we have here all the elements of a simple motor. If this loop were free to

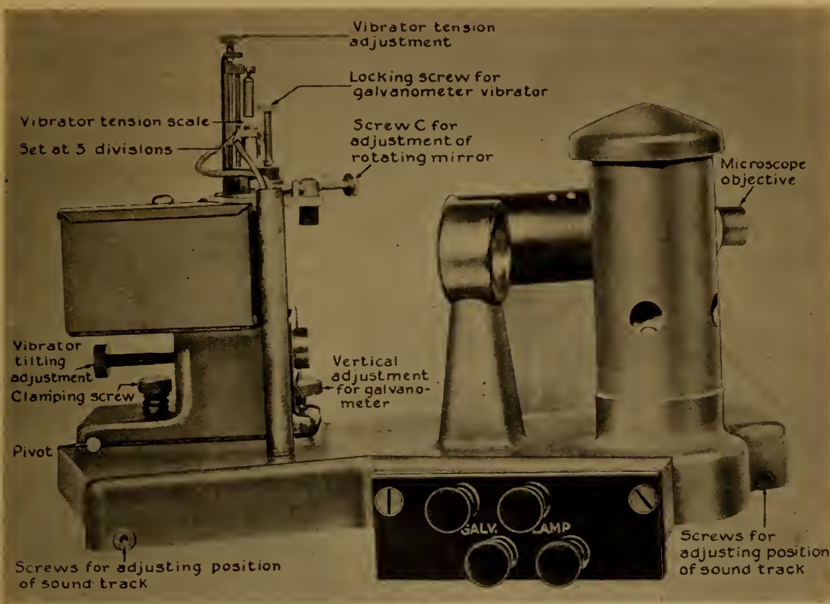

FIGURE 2

Galvanometer and Optical System.

turn, it would rotate like the armature of a motor. Being tied down tightly on each end, however, it vibrates when the alternating current signal from the amplifier passes through it. This vibration about a vertical axis occurs in that portion of a loop between the two ivory bridges and the little mirror, being firmly attached to both sides of the loop, vibrates also.

The tension applied to these wires determines their natural period. By natural period, I mean the point at which the vibrator will give the greatest response for a certain current input. All vibrating bodies have a natural period or resonance point and this device is no exception to the rule. Its period is approximately 6000 cycles. The peak in the case of this vibrator is a comparatively small one, being of the order of perhaps five to six db. This over-response is not bad enough to cause a great deal of distortion in itself, but its action is further neutralized by immersing the entire vibrating unit in a container filled with a mineral oil.

This vibrator is quite a sensitive device. It requires only 100 milliamps to give a full scale deflection. Since this vi-

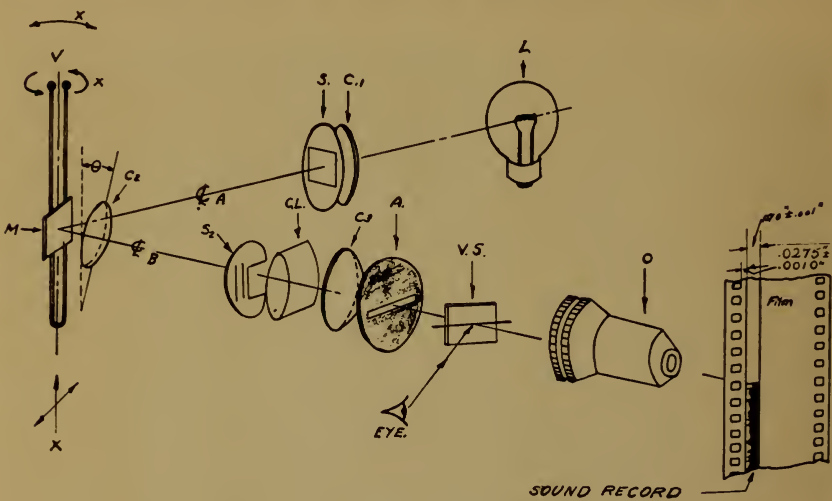

FIGURE 3

Schematic diagram of galvanometer and optical system. L—Prefocused exposure lamp. C1—Spherical lens. S1—Light stop. C2—Galvanometer lens. V—Galvanometer vibrator. M—Galvanometer mirror. S2—Scale. C.L.—Cylindrical lens. C3—Spherical lens. A—Aperture. V.S.—Viewing Screen. O—Microscope objective. X—Directions of movement for alignment.

brator is part of an optical system you will be interested in seeing how it is used.

Fig. 3 is a schematic diagram of the entire arrangement Light is generated by a concentrated filament gas filled lamp (L) and focused by a double convex condensing lens (C1) onto the mirror of the vibrator (M). The other lens shown as (C2) is a plane lens which acts as a window in the galvanometer housing and keeps the oil from coming out. It is placed at an angle so that light will not be reflected from its surfaces into the rest of the system. The circular disc with a square hole in it, is a light stop and merely cuts off the color fringe produced by the aberration of the lens.

The light is reflected from the mirror thru a cylindrical lens (C.L.) This lens condenses the beam of light in one direction only. It then passes thru another condenser (C3) on to a disc A. This disc has cut into it, as shown, a slit .003″ wide thru which the light passes into a microscope objective. This objective focuses the image of the slit on the film, reducing it at the same time by a 4 to 1 ratio. This results in a light image on the film .00075″ wide and .070″ long.

Under normal operating conditions, only one-half the sound track is exposed. The light which normally would expose the

Bicycle Bell *Orchestra* *Woman's Voice*

FIGURE 4

Examples of Photophone variable area sound track showing different complex wave forms.

other half of the track is intercepted by this white celluloid screen. This has graduations marked on it denoting the limits thru which the light beam may move without over-modulating the film or, in other words, without overshooting the sound track.

As alternating current is fed from the amplifier to the vibrator, it causes the loop to twist back and forth. This rocks the mirror and increases or decreases the length of the slit image on the film. The width of the slit image being at all times constant, the result is a sound track of varying width which has the appearance of a serrated edged exposure. The shape of these saw teeth, of course, depends on the shape of the original sound wave together with what distortions have been introduced into the system. The higher frequencies show as peaks close together like a fine tooth comb and the amplitude or width of the peaks measured across the track, is proportional to the loudness of the original sound.

Microphotographs of serrated edge or variable area sound track are shown in *Fig. 4.*

The power for moving the film past the optical system at a constant rate of speed of 90 ft. per minute, is supplied by a synchronous motor from the power source which supplies the camera motors. In ordinary studio operation, all of these motors are thrown across a three phase central station power supply without any intermediate compensators. A gear mechanism is used to reduce the speed of the motor so that it will drive a sprocket for pulling the film from the supply magazine, the recording drum, through a special compensating mechanism, and the take up on the film magazine. If there were no variation in different grades and stocks of film, no compensator would be necessary. Every different type of film, however, seems to have varying amounts of shrinkage and it becomes necessary to provide a means of overcoming this and still maintain constant speed past the exposure light.

The operation of the compensating mechanism for type R-3 recorder is shown schematically in *Fig. 5.* The synchronous motor drives the fly-wheel through a pinion and gear. The gear is attached to the flywheel by means of a spring coupling. On the same shaft with this flywheel is a belt drive for the take-up, cone "C" and sprocket "S" which pulls the film from the film magazine at constant speed. This shaft is also arranged so that it floats on a supporting arm. Pressure is exerted on this arm by a spring which forces the cone "C" on to an idler "A" and causes the idler to revolve by friction. Pressure from the cone "C" is transmitted through the idler to the cylinder "B" which is also driven by friction and causes the recording drum "D" to revolve. It will be noticed that the speed of the drum is determined by the position of idler "A", if it is in position "n", the recording drum will revolve slower than in position "m". The position of the idler is changed by a lever which tilts the idler and causes it to change its position on the cone "C". The tilting lever is controlled by a compensating roller. Thus, if the film has been stretched, a loop tends to form between the sprocket "S" and the recording drum "D". This allows the roller to move downward causing the compensator to move the idler into a position to increase the speed of the recording drum and take up the

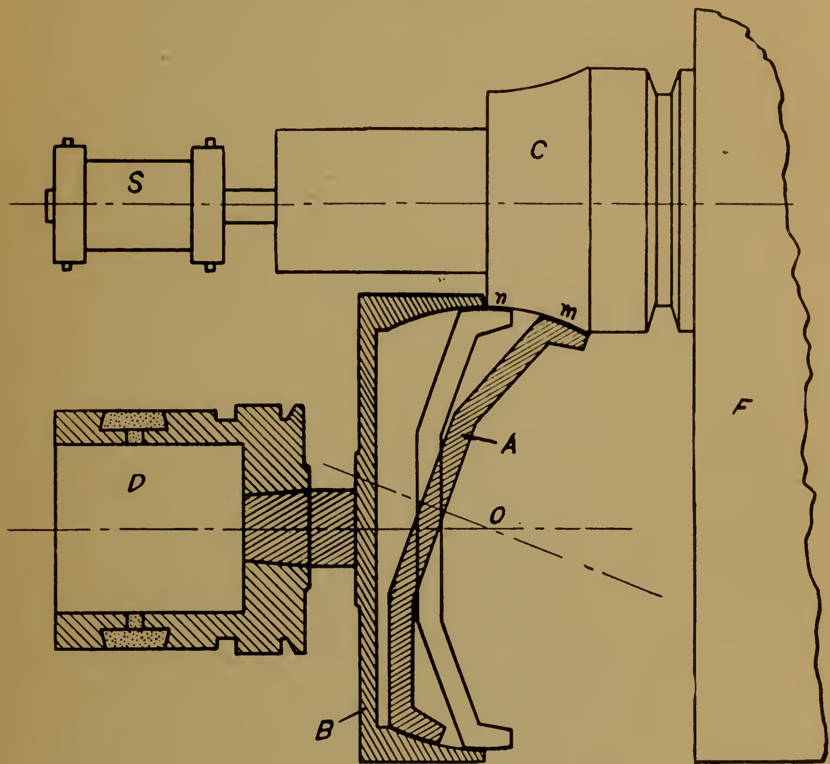

FIGURE 5

Schematic diagram of compensating mechanism showing transmission of power from the motor to pull-down sprocket and recording drum.

slack film. When the film shrinks, the reverse action takes place. The position of the compensator roller is shown by an indicator on the recorder door when it is in the operating position.

Wipers are provided to keep the friction drive surfaces of the idler and cone clean. These must be kept in perfect condition since proper operation of the recorder depends largely on these parts.

In order that the sound track may be printed in perfect synchronism with the picture which is exposed at the same time, a marker light is provided on the recording machine and on each

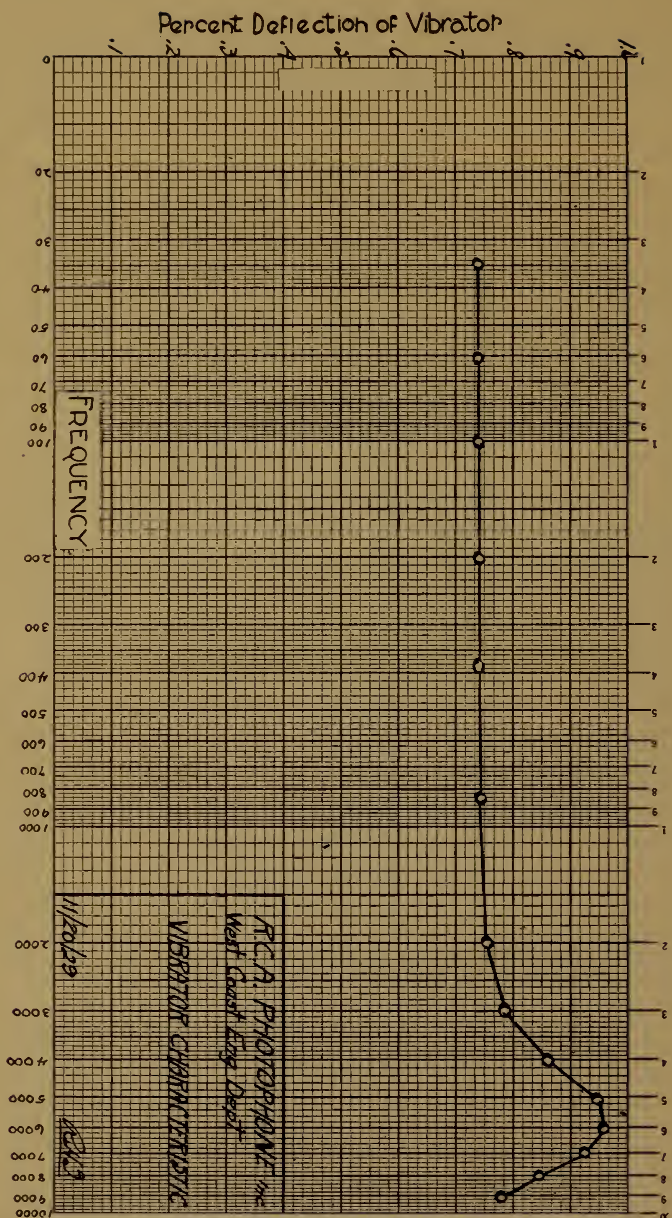

FIGURE 6

Chart showing the response or deflection of a Photophone vibrator when constant voltage at all frequencies is applied to the terminals of the vibrator.

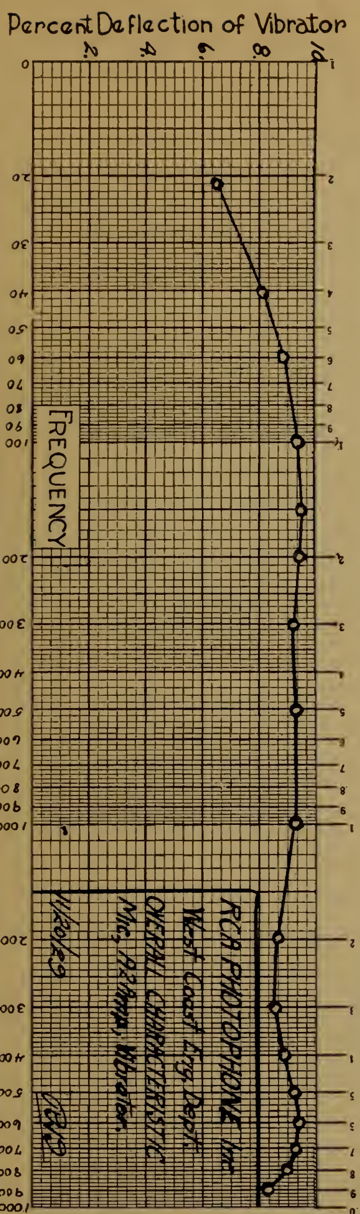

FIGURE 7

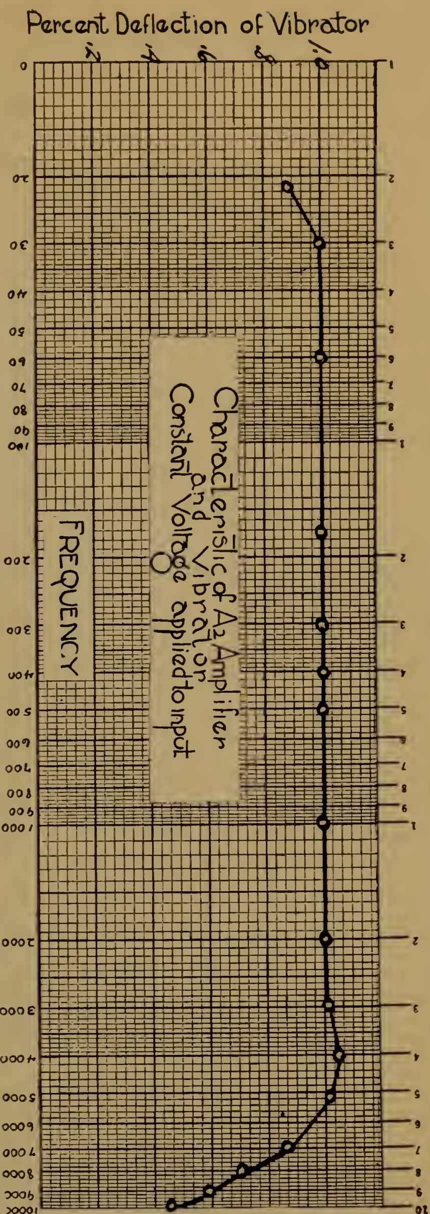

FIGURE 8

Figure 7 shows the relative sensitivity of the Photophone amplifier and vibrator combined when constant voltage is applied to the input of the amplifier.

Figure 8 shows the relative sensitivity of the entire recording system consisting of microphone, amplifier and vibrator. This curve was determined by applying constant sound pressure to the microphone and measuring the output in terms of vibrator deflection.

camera. These lamps expose a portion of the film outside the sprocket holes and are connected in series so that instantaneous exposures are made on the sound negative and picture negative.

In order that the rate of exposure of the sound track may be constant and uniform on all takes, the brilliancy of the light beam is measured by means of a photometer. A photometer is a detachable device which can be plugged into the recorder drum while the exposure lamp is being adjusted. The small lamp in the photometer is always operated at a certain value of current, this value being determined by careful sensitometric measurements. The brilliancy of the exposure lamp is then compared with the brilliancy of the photometer lamp and when the photometer screen shows the same brilliancy for both, the exposure lamp is burning at its optimum value.

The sound track negative is developed in the laboratories to a density of about 1.6. This provides for a light transmission of about 2½%. These figures are average and are adherred to because above this density the fog factor increases to such an extent that the high frequency striations become filled in or indistinct and produce a fuzzy reproduction.

MOTION PICTURE SOUND RECORDING BY FOX FILM CO.

*E. H. Hansen**

The Fox Movietone system differs from other types of film recording in the translating device of the amplified sound currents. The Movietone method utilizes a slit of constant width and a varying light intensity known as the Aeolight.

This Aeolight was developed by Theodore W. Case, and is a gaseous discharge tube which varies its illumination in accordance with the impressed speech currents. In the use of the light valve, which may be termed an electro-mechanical translator, it is possible to provide for certain deficiencies by the tuning of this element. With the Aeolight it is necessary that all equalization be provided in the electrical circuits.

Fig. 1 is a photograph of the Aeolight.

The Aeolights are tested for the purpose of determining the intensity of light with a known standard so that uniformity of exposure may be accomplished, and the modulation capacity or overload and extinguishing limits established.

In Movietone recording the Aeolight is not focused upon the recording film but rather a portion of its illumination is permitted to pass through a quartz slit, which is in contact with the film. This slit and the attendant Aeoligh holder are shown in *Fig. 2*. It consists of a quartz base .2 of an inch square by 20 mills thick, upon which is placed a silver coating. This silver coating is then engraved to the desired slit width and length, usually 0.01 by .0008 inches, and is then covered with a quartz glass, the thickness of which is 1 mill at a point opposite the slit. The slit is then mounted on a floating metal shoe and is a part of the Aeolight tube holder, which is inserted in the sound camera in such a manner that contact is made with the recording film at a pre-determined point on the sound camera sprocket.

The sound camera consists of a light, tight box, with grooves

**Operating Head of Movietone Division, Fox Studios.*

and locking arrangement for standard magazines. The film is driven by a single sprocket. This sprocket is rotated by a synchronous motor through the proper reduction worm gearing, and the necessary mechanical filtering devices. As in the Western

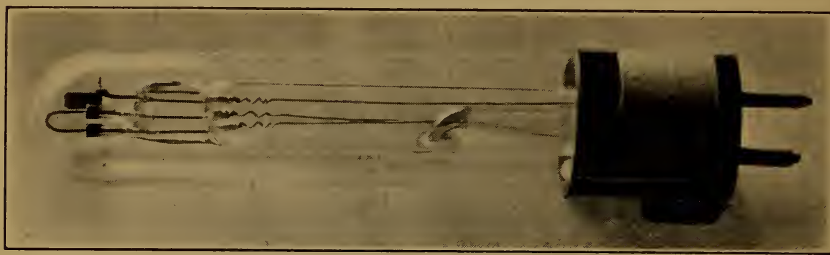

FIGURE 1

FIGURE 2

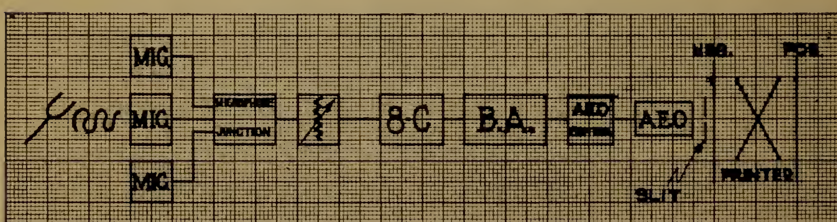

FIGURE 3

Electric system, the electrical gearing type of drive is employed permitting the synchronous rotation of sound cameras and the numerous picture cameras. The sound and picture camera films are marked, after the proper interlocking has occurred, with pencils, and the sound camera film is given scene numbers at the

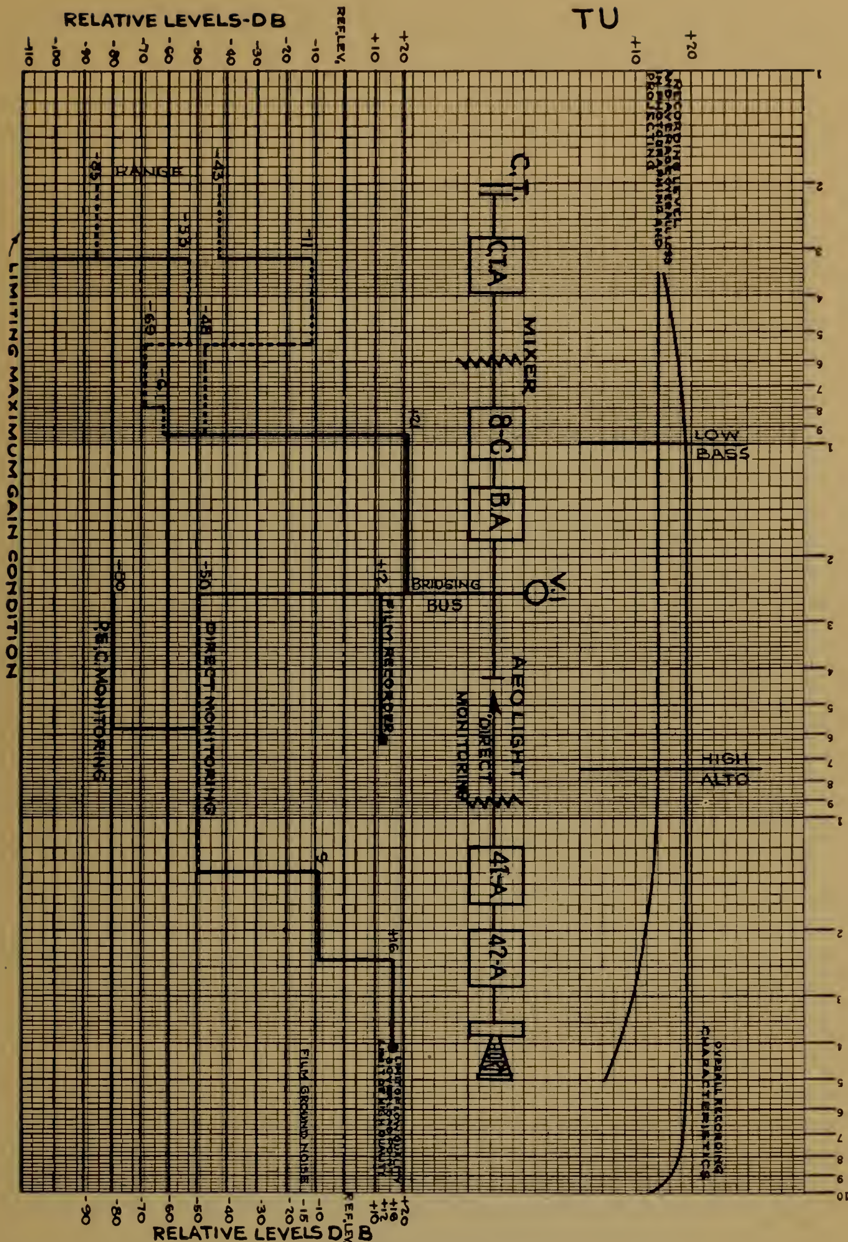
RELATIVE LEVELS-DB
TU
REF.LEV.
RANGE
LIMITING MAXIMUM GAIN CONDITION
C.T.
C.T.A
MIXER
8-C
8-A
V.I
BRIDGING
BUS
AEOLIGHT
DIRECT
MONITORING
41-A
42-A
LOW
BASS
HIGH
ALTO
P.E.C. MONITORING
DIRECT MONITORING
FILM RECORDER
FILM GROUND NOISE
OVERALL RECORDING CHARACTERISTICS
RELATIVE LEVELS DB

FIGURE 4

end of the scene by the same method of writing directly in the sound camera.

In *Fig. 3* is represented schematic diagram showing the pickup, amplifier and recording channels. It will be noted that

FIGURE 5

the customary Western Electric type of condenser microphones are used and connected in the usual way, first, through junction boxes, and then through mixing panels, to what is known as the master mixer. From this master mixer the output is connected to a standard 8C amplifier. The output of this amplifier is then introduced into what is known as a bridging amplifier, and any number of bridging amplifiers may be employed for simultaneous recordings on more than one sound camera. The output from the bridging amplifier then passes through the Aeolight control panel, which provides for the operation of the Aeolight at its proper working points. There is also provided a dummy circuit for monitoring when it is not desirable to burn the Aeolight.

A level diagram is shown in *Fig. 4*, which graphically represents the amount of energy prevailing at different parts of the recording circuit. Under CT, which is the abbreviation for condenser transmitter, we find that this unit plus the condenser transmitter amplifier is capable of a range of approximately

FIGURE 6

45 db from minus 85 db to minus 43 db. The passage of these voice currents through the mixing panel is attenuated approximately 6 db, and then it is raised in the 8C amplifier to a maximum gain of approximately 80 db. The level at the Aeolight is approximately plus 12 db, and for direct monitoring the drop across a resistor in the Aeolight circuit provides a new monitoring level of approximately 50 db, which is then raised in an AC operated amplifier of the type 41-A and 42-A, to approximately plus 16 db for final output into the monitoring horns.

At the top of the graph is represented both the overall recording characteristics, and then on a lower scale is shown the average overall loss from the recording film processing and projection systems. Two reference points of pitch are shown.

FIGURE 7

On the right of the graph is also shown the average ground noise position of the print, which is normally at a minus 15 db. There is also provided means for monitoring from the Aeolight through a photo-electric cell, and this reference level is shown to be minus 80 db, at the photo-electric cell amplifier output.

The physical layout of this equipment is illustrated in *Fig. 5*, which shows the arrangement for permanent wiring on stages, and is the amplifier bay overlooking the stage. The outputs from the microphone junction box are brought to the mixing panel on the right, thence to the master mixer, from which it goes into the amplifier located in the amplifier room.

There is also mounted in this monitoring bay, shown at the left of the illustration, the control switches for all sound and picture cameras, as well as a system of signal lights for the coordination of recording between the various photographic, sound recording and directorial departments. A volume indicator is shown in the center of the photograph, the purpose of which is to read the levels of speech current existing at the terminals of the Aeolight.

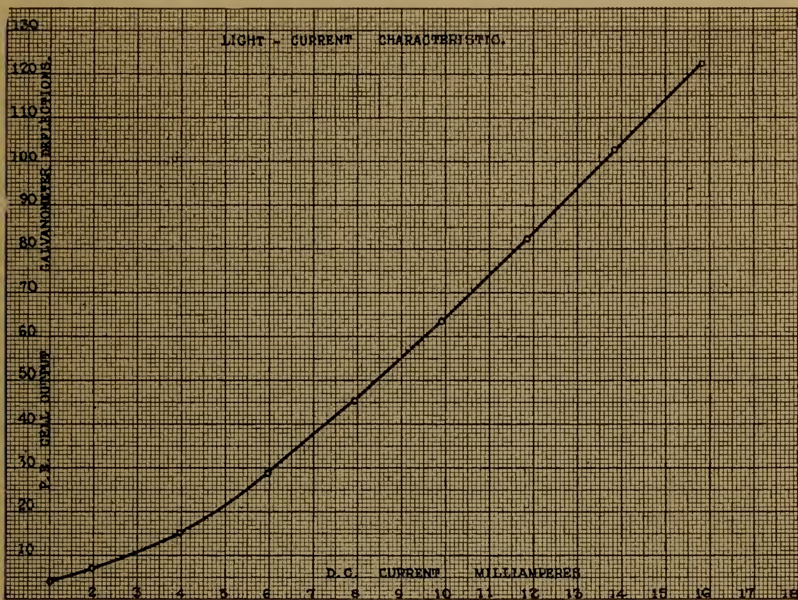

FIGURE 8

Fig. 6 shows the amplifier room in which are additional monitoring amplifiers.

Fig. 7 shows the sound camera, as well as the synchronous distributing system with its attendant tuned control box.

It is necessary, when discussing any recording method, to consider the photographic processing directly with the problems and the characteristics of the electrical and recording light circuts. It will be observed in *Fig. 8* that the illumination from an Aeolight is proportional to the amount of current flowing through it. The Aeolight burns at a pre-determined exposure with a steady DC component, and this is varied by the introduction of speech currents in addition to the fixed DC current.

Positive stock is employed in Aeolight recording, and with the usual laboratory development the unmodulated illumination will occur half way up in the linear portion of the characteristic curve showing exposure and transmission. This curve is shown

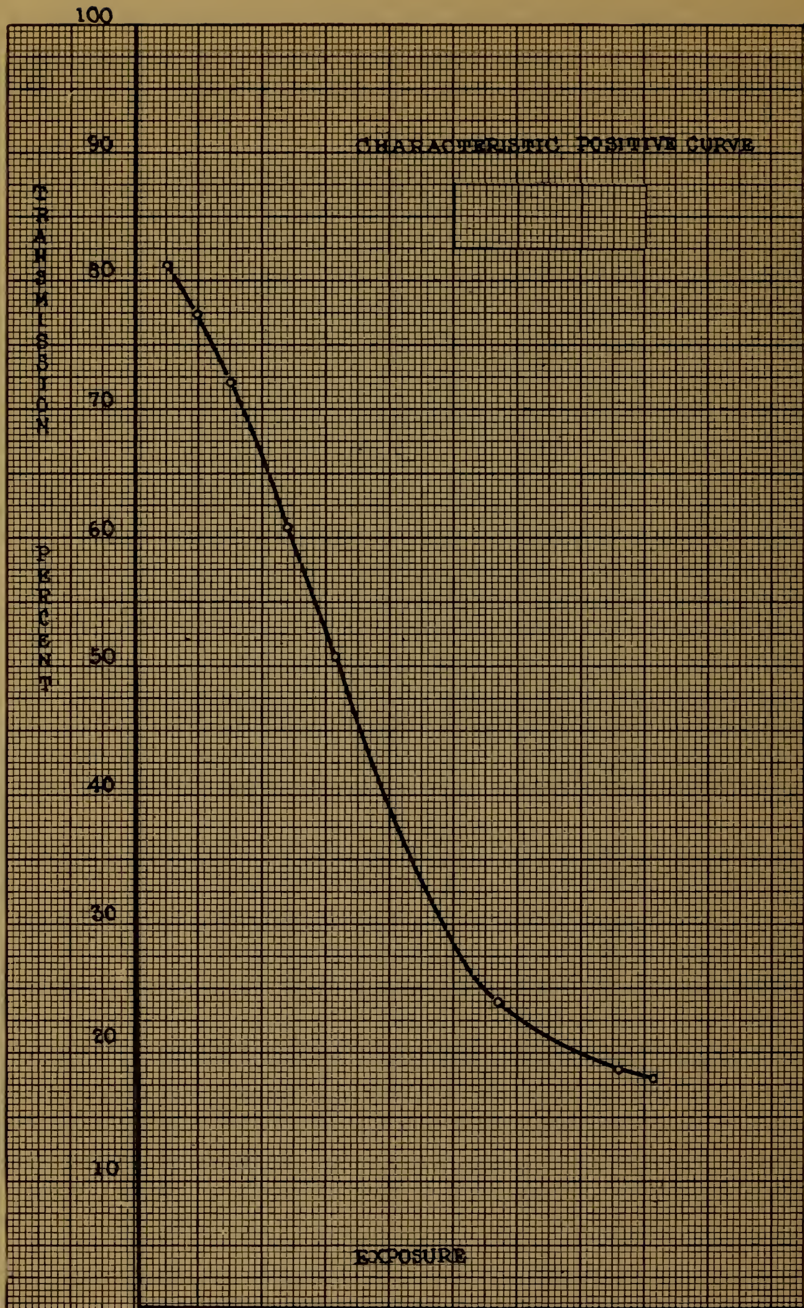
CHARACTERISTIC POSITIVE CURVE
TRANSMISSION PERCENT
100
90
80
70
60
50
40
30
20
10
EXPOSURE

FIGURE 9

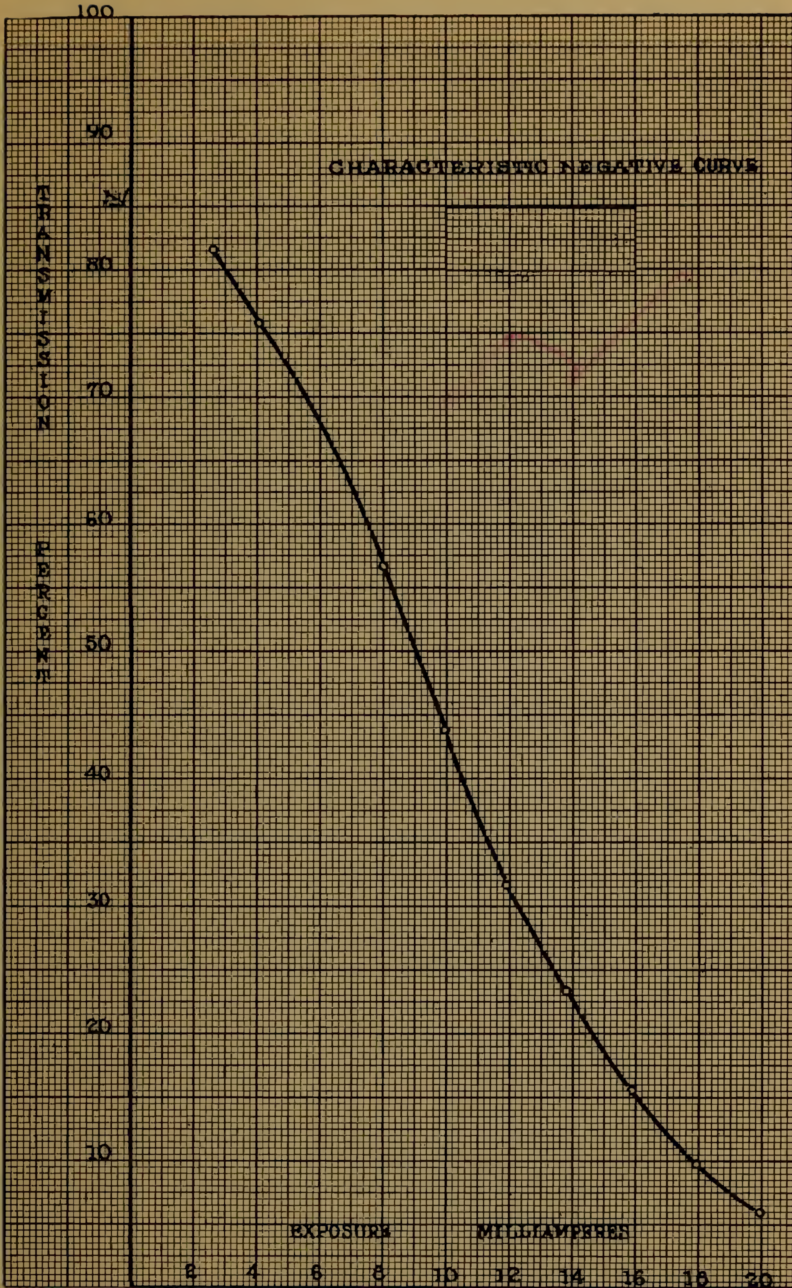
CHARACTERISTIC NEGATIVE CURVE
TRANSMISSION PERCENT
100
90
80
70
60
50
40
30
20
10
EXPOSURE MILLIAMPERES
2
4
6
8
10
12
14
16
18
20

FIGURE 10

FIGURE 11

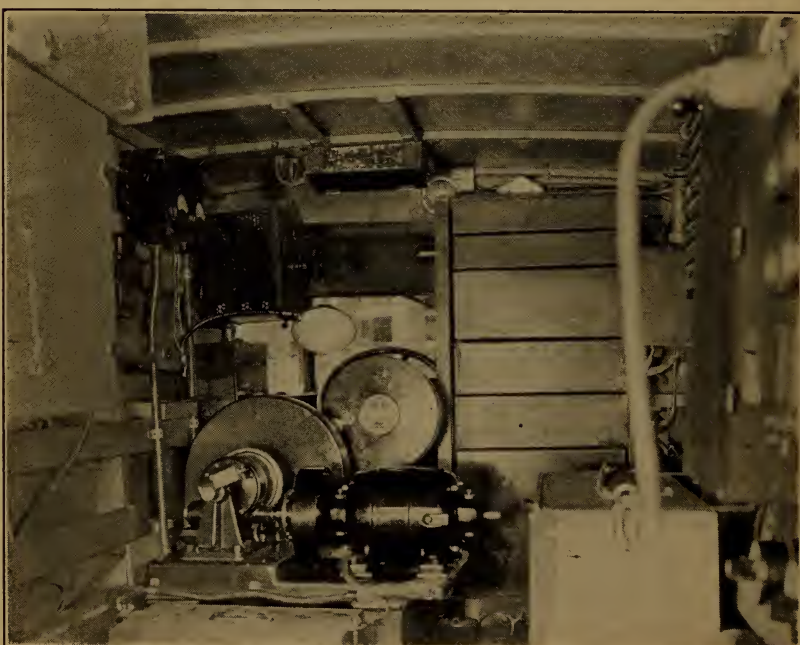

FIGURE 12

in *Fig. 9.* Daily test exposure strips are sent to the laboratory in order to determine the uniformity of development, and as a check on the standards of illumination.

In printing, the double exposure method is employed, and a

FIGURE 13

printer point is chosen which will give the desired changeover from the negative to the positive linear characteristic. This is shown on *Fig. 10.* It is necessary that printers be regularly inspected in order that poor contact and aperture troubles be discovered. Before released from the laboratory, transmission measurements are made on all prints, and this is accomplished by means of photo-cell densitometers.

The Fox Film Company has found it advantageous to employ equipment that is portable in nature, and has designed a type that answers these requirements. Photographs are shown in *Fig. 11* of the interior of a portable recording system, and it will be observed that, due to the necessary compression on account of space requirements, many of the control panels on the stages are combined on a single relay rack. The circuits, however, are the same. Portable monitoring amplifiers are provided and loud speakers with small monitoring booths for use in the field. Fig. *12* is a view in this truck showing the recording camera. *Fig. 13* is the trailer which carries the distributor and tuned control box, as well as all cable equipment.

The technique of recording by the Fox Movietone system does not vary substantially from that advocated for light valve methods. Outdoor conditions are probably more often encountered and it is not always desirable to apply studio technique due to the fact that conditions are widely dissimilar. It has been necessary to provide means for killing wind noises and extraneous sounds, and to provide mobile stands for the movement and placement of microphones.

MOTION PICTURE SOUND RECORDING BY WESTERN ELECTRIC METHOD

*Dr. Donald MacKenzie**

The object of all recording is to furnish a sound which would be indistinguishable from the sound one would get from the real source if it were there. At best, it will be no better than direct transmission from the microphone which picked it up in the set, out to the horn which reproduces it in the theatre. From the point at which the recording device comes in, to the point where the photocell furnishes current for the amplifier, we have done nothing but introduce a delay circuit to stop the currents coming from the microphones and store them up until we want record will be nothing more than a delay circuit. The effort to them to actuate a loud speaker. You will see that the permanent give a complete illusion, then, is dependent upon the success of the transmission line and it is affected with all of the disadvantages of listening with one ear (one microphone) whereas you have two ears. The acoustical conditions which are favorable and give a fair illusion are discussed by Mr. Maxfield.

The recording method I wish to describe is used in the Western Electric system, and depends upon the light valve to effect modulation of the light on the sound negative.

The Photophone method described by Mr. Townsend is a variable area method. The method Mr. Hansen described is a variable density method, and I am about to discuss another variable density method. In Mr. Hansen's device we have a light source, whose intensity is varied, shining on the film through a slit of fixed width. The factors of intensity and time constitute the exposure and one or the other is varied. In the Fox device, the intensity is varied and the time of exposure is constant. In the light valve shown in *Fig. 1*, you have a shutter opening and closing. That shutter is focussed on the film to form a line ½ mil wide when undisturbed and varying from zero to twice its

**Technical Service Engineer, Electrical Research Products, Inc.*

normal width. The intensity of the light is unchanged. A fixed source of light shines upon a loop, the sides of which open and close and the width of the image as it varies from zero to one mil varies the time it takes for the film to pass the exposure point.

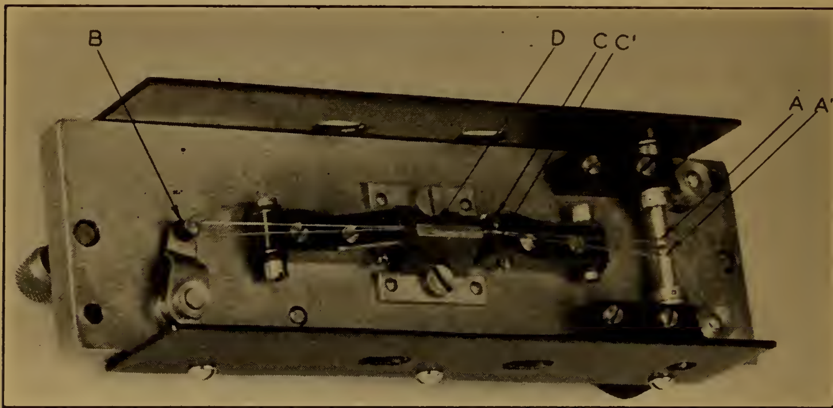

FIGURE 1

Fig. 1 shows a photograph of the light valve, invented in 1922 by E. C. Wente of the Bell Telephone Laboratories. Essentially, it consists of a loop of duralumin tape suspended in a plane at right angles to a magnetic field. The tape, 6 mils wide and 0.5 mil thick, is secured to windlasses A and A^1 and stretched tight by the spring held pulley B. At points C and C^1 insulated pincers confine the central portions of the tape between windlasses and pulley to form a slit 1 mil wide. Supporting this loop and adjusting devices is a slab of metal with central elevation D, which constitutes the armature of an electromagnet. The central portions of the loop are supported on insulating bridges to lie 3 mils above the face of D; here the sides of the loop are centered over a tapered slot, 8 mils wide by 256 mils long in this plane, opening to 204 mils by 256 mils at the outside face of the armature. Viewed against the light, the valve appears as a slit 1 mil by 256 mils.

The electromagnet core has a similar elevation opposing D across an air gap of 8 mils which closes to 7 mils when the magnet is energized from a 12 volt battery. A tapered slot in the magnet core begins 8 mils wide by 256 mils long and opens with the same taper as the slot in the armature. When the assembly of magnet and armature is complete, the valve constitutes a slit 1 mil by 256 mils, its sides lying in a plane at right angles to the lines of force and approximately centered in the air gap. The windlasses A and A^1 , one of which is grounded, are connect-

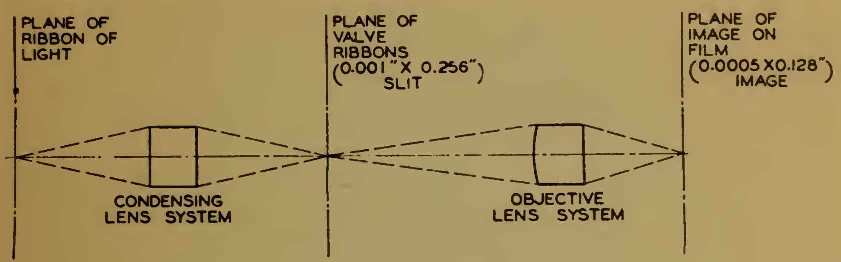

DIAGRAM OF OPTICAL SYSTEM
IN STUDIO RECORDING

FIGURE 2

ed to the output terminals of the recording amplifier. If the magnet is energized and the amplifier supplies current from an oscillator, the duralumin loop opens and closes in accordance with the current alterations. Length and tension of the vibrating part are so chosen that its resonance is at 8500 cycles which puts it out of the range of the conspicuous cycles in speech and music.

If this appliance is interposed between a light source and a photographic film we have a camera shutter of unconventional design. *Fig. 2* shows a diagram of the optical system for studio recording. At the left is a light source, a ribbon filament 18 ampere projection lamp, which is focussed on the plane of the valve. The light passed by the valve is then focussed with a 2 to 1 reduction on the photographic film at the right. A simple achromat is used to form the image of the filament at the valve plane, but a more complicated lens, designed to exacting specifications by Bausch and Lomb, is required for focussing the valve on the film. The undisturbed valve opening appears on the film as a line ½ mil by 128 mils, its length at right angles to the direction of film travel. The width of this line varies with the sound currents supplied to the valve, so that the film receives a varying exposure: light of fixed specific intensity through a varying slit. (See *Fig. 6* on page 381.)

Both the aeo light and the light-valve result in variable density records, and the transmission of the positive print at every point should be proportional to the exposure of the negative at the corresponding point. If that can be accomplished, then we deliver to the photoelectric cell a light the same as it would receive had there been no record interposed.

Fig. 3 shows a studio recording machine with the door of the exposure chamber open. In this machine the film travels at 90 feet per minute, and the sound track is made at the edge away from the observer. The line of light, the image of the valve, overruns the perforations by 6 mils, extending toward the center of the film 122 mils inside of the perforation line. The right-hand sprocket serves to draw film from the feed magazine above and to feed it to the take-up magazine below; this sprocket is driven from the motor shaft through a worm and worm-wheel. The left-hand sprocket engages 20 perforations and is driven through a mechanical filter from a worm and worm-wheel similar to that driving the feed sprocket. The mechanical filter enforces uniform angular velocity of the left-hand sprocket which carries the film past the line of exposure: the focussed image of the valve. Balancing of the flywheel which forms part of this mechanical filter holds the angular velocity constant to one-tenth of one per cent, despite the imperfections of the driving gears.

In *Fig. 3* the photograph shows a photoelectric cell mounted inside the left-hand sprocket, which carries the film past the line of exposure. Fresh film transmits some 4 per cent of the light falling on it, and modulation of this light during the record is appreciated by the cell inside the sprocket. This cell is connected to a preliminary amplifier mounted below the exposure chamber, and with suitable further amplification the operator may hear from the loud speaker the record as it is actually being shot on the film. Full modulation of the valve implies complete closing of the slit by one side of the wave of current; this modulation should not be exceeded or photographic overload will abound.

Fig. 4 is a skeleton diagram of the studio recording channel, showing the recording amplifiers and the direct and photocell monitoring circuits.

It is my purpose here to describe the procedure necessary to render the film as nearly perfect as possible, and produce a satisfactory delay circuit. We ask of the film or any other recording device that it should take the current fed to it and reproduce that without distortion. By that is meant that all of the currents which come up should be reproduced without omission and without changing the relative proportions of the currents, that no other currents due to distortion of wave shape, no frequencies

FIGURE 3

other than those in the original sound source should appear in the reproduced record, and there should be no static or noise—ground noise on the film or surface noise on the disc.

At the michrophone you pick up whatever noise there is on the set in addition to the signal. If the cameras are noisy, if the population on the set is noisy, such noises will appear as contributing to the ground noise although they are not due to the recording itself. There is some noise in amplification and often some cross-talk due to pick-up from neighboring circuits; this may be called system noise. Set noise is the most important, and system noise may be reduced to nearly nothing by careful maintenance. The noise from the film when carefully processed is small in comparison to the others I have mentioned.

Obviously some sounds will be recorded but lost in the ground noise of the system and film. There will be other sounds which will overload the valve. How wide a difference in level can be recorded and reproduced without distortion on the one hand and without being lost in the ground noise on the other? As a matter of fact, under experimental conditions with everything in our favor, records were made in 1925 at the Bell Telephone Laboratories, of the Capitol Theatre Orchestra in New York with a range of 60 d.b. between the loudest peak and the ground noise. In that case the theatre noise itself determined the lower level. Sixty decibels is a much narrower range than you can hear beteen the threshold of audibility and the threshold of feeling. But the noise heard by the audience is never zero because the noises in the theatre—the ventilating system, the breathing and involuntary shifting of the audience—are always well above the threshold. If you were able to record in every case a range of 60 decibels you would satisfy almost all requirements of recording. We do not record that except under the most favorable circumstances so far, but we can claim that the range of 40 decibels is commercially to be expected for careful work between the overloading signal and the ground noise. 40 decibels between the ground noise and the overloading signal means you can easily record the range of 30 decibels between fortissimo and pianissimo and keep the pianissimo free from noise. That is the range between a whisper and a yell.

The success of our efforts to reduce the ground noise due to the film record itself, is dependent upon our preventing parasite modulation of exposure, such as would be caused by light reflected from the sprocket teeth which move the film past the exposure line, and in avoiding local variations in density of the negative or of the positive print, due to irregular development or to contamination of the developer, as well as possible variations in the film stock itself. With careful processing and care in protection of the negative exposure, the film's contribution to the ground noise can be kept below the other sources of undesired noise, namely, system and set noises.

The film technician is called on to provide suitable negative exposure and positive timing and appropriate development of the negative and the positive so that the negative exposure as it varies from moment to moment shall appear as a positive transmission similarly varying. In other words, the contrasts of the negative exposure must be faithfully reproduced as contrasts of positive transmission. To accomplish this, we go back to the work of Hurter and Driffield, who forty years ago established the requirements.

Hurter and Driffield showed that every photographic emulsion may be described by a characteristic curve, known since their work as the H and D curve. It is convenient to plot the data in logarithmic terms to show the relation between the exposure and the resulting photographic effect. We choose the logarithm of the exposure, measured in meter-candle-seconds or in any other convenient units of light energy, and plot the logarithms of successive exposures against the resulting densities. Photographic density is defined as the logarithm of the opacity. Opacity itself is the reciprocal of the transmission, which is the ratio of the amount of light transmitted by a piece of developed exposure to that which falls upon it. We shall for the present avoid the troublesome technicalities of specular and diffuse densities, and consider that satisfactory measurements have been made of the exposure and of the density resulting.

If a series of graded exposures are made on a series of areas of a photographic film, and a curve plotted between the logarithms of exposures as abscissas and the developed densities as ordinates, we find the underexposure region represented by a portion of the curve concave upward, followed by a straight portion corresponding to the region of correct exposure, and finally the overexposure which appears as a curve concave downward. The slope of the straight line portion is determined, for any particular type of emulsion, by the development—this slope is called gamma and defines contrast. *Fig. 5* exhibits an H and D curve obtained from Eastman positive film.

Curves of this kind are obtained for the emulsions for the negative sound record and for the positive prints, for various developments. It is thus possible to determine what development to give for any desired contrast.

Hurter and Driffield showed that perfect reproduction in

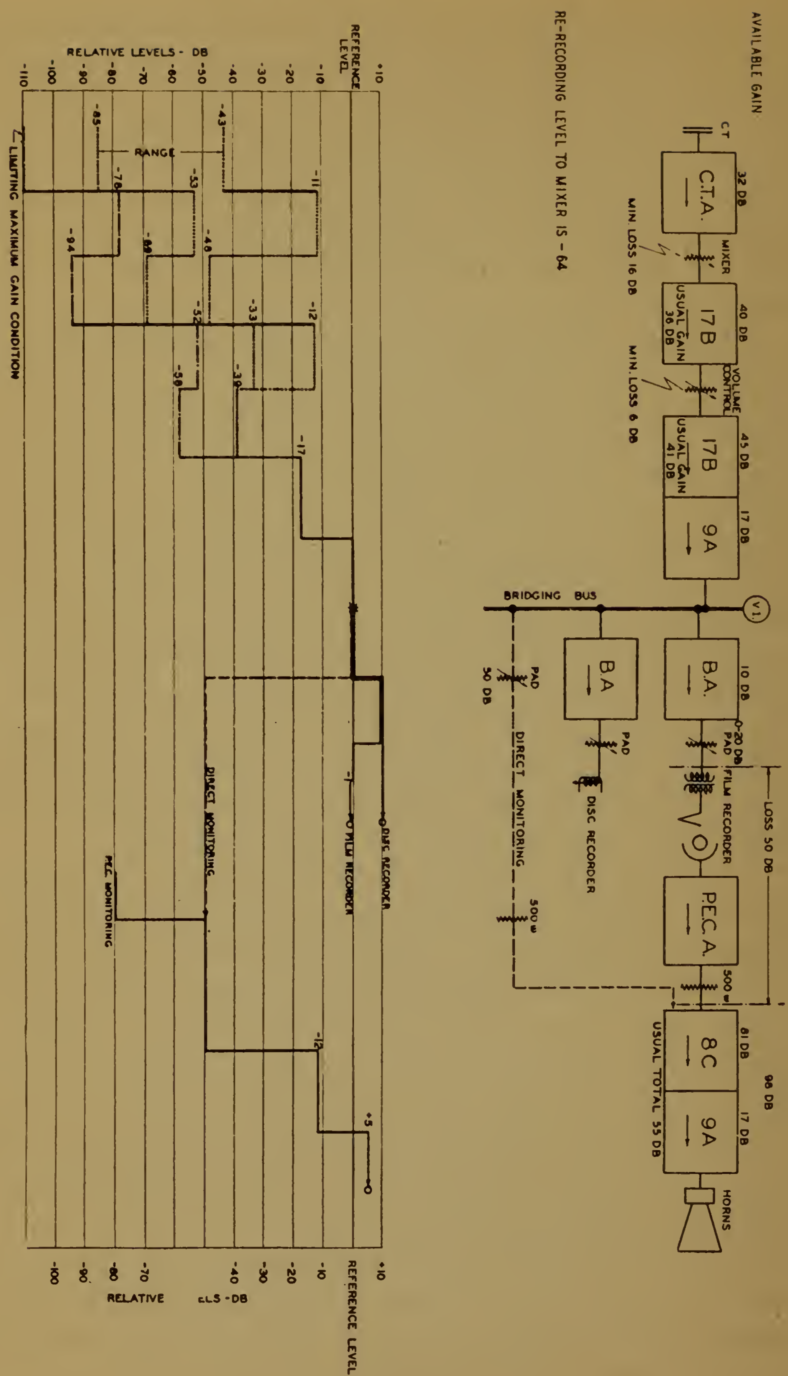
AVAILABLE GAIN
RE-RECORDING LEVEL TO MIXER IS – 64
CT
C.T.A.
32 DB
MIXER
MIN. LOSS 16 DB
17B
40 DB
USUAL GAIN 36 DB
VOLUME CONTROL
MIN. LOSS 6 DB
17B
45 DB
USUAL GAIN 41 DB
9A
17 DB
BRIDGING BUS
V.I.
B.A.
10 DB
B.A
PAD
0-20 DB PAD
DISC RECORDER
FILM RECORDER
LOSS 50 DB
PAD 50 DB
DIRECT MONITORING
500 ω
P.E.C.A.
8C
81 DB
9A
17 DB
96 DB
USUAL TOTAL 55 DB
HORNS
RELATIVE LEVELS - DB
REFERENCE LEVEL
RANGE
LIMITING MAXIMUM GAIN CONDITION
DISC RECORDER
TO FILM RECORDER
DIRECT MONITORING
P.E.C. MONITORING

FIGURE 4

the positive of the contrasts of the negative exposure can be had only if we arrange to confine the exposures on both the negative and print to the straight line portion, and furthermore arrange the development of both films so that the contrasts are reciprocal.

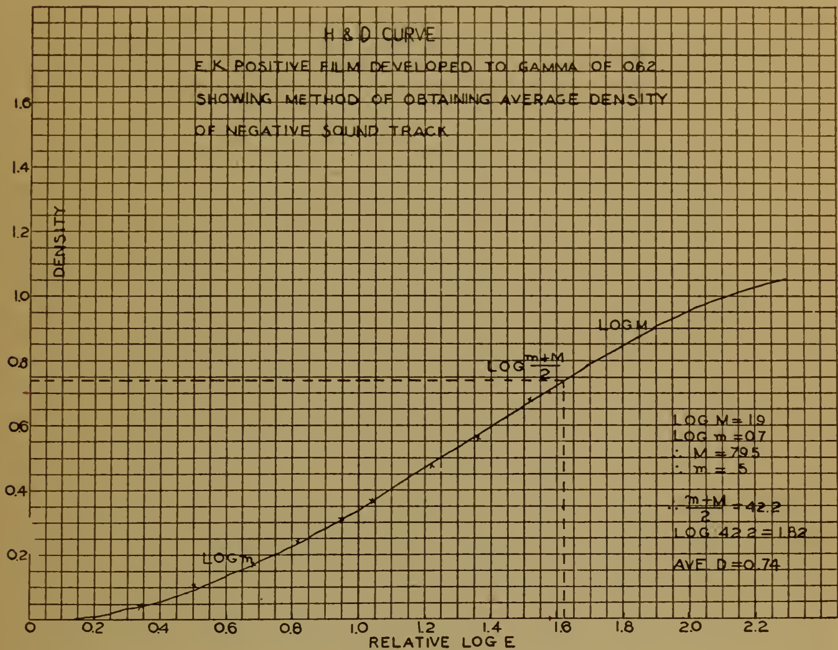

FIGURE 5

It can be demonstrated that if the exposures are restricted to the correct exposure regions, and if the gammas of development are made to have reciprocal values, the variations in the negative exposure are properly reproduced as variations of positive transmission.

It is to be emphasized that the photographic problem of sound differs from that of the picture. The sound record requires exact contrast reproduction, whereas the picture may call for an enhancement of the brightness values of the scene photographed. For this reason it is an advantage to make sound and picture negatives on separate films. The picture negative can then be developed as desired and the sound negative can be given the treatment which insures a negative gamma the reciprocal of that of the release print development.

Then it must be pointed out that the ordinary methods of sensitometry which are used to determine the contrast factors (gammas) of development require some correction to take into account the difference between exposures in the sound recording machine, which exposes an element of the film for a very short time to a very bright light, and those usually made in sensitometry; further, account must be taken of the conditions of reproduction, involving the manner in which the reproducing light is focussed on the film and the electrical circuit connecting the photocell to its amplifier.

The lamp current to be used in the recording machine must be determined by test, in order to produce in the film an exposure for the undisturbed light valve such that doubling this exposure when the valve is open to double width (full modulation) shall be just clear of overexposure for the emulsion used and for the development it is decided to give the negative sound record. Unmodulated tracks should be made with various lamp currents, developed all to the chosen contrast and that current determined which results in the density shown on the curve of *Fig. 5* corresponding to the ideal negative exposure.

From investigations made for the purpose, it is possible to tabulate appropriate pairs of values of positive and negative gammas and appropriate densities for the unmodulated tracks. The H and D curves are to be obtained from sensitometer strips prepared in the usual way, and these densities are to be measured diffusely. For example if the practice of the release print development involves a positive gamma of 1.75, the proper negative gamma for the sound record is 0.6 and the proper density of the unmodulated negative track is 0.6 referred to the fog density. A density of 0.5 is satisfactory for the unmodulated positive track. These values are accurate for Eastman positive film and are substantially so for the other positive stocks which might be used in recording and in printing.

The limits of permissible modulation of negative exposure when using the light valve can be determined from observation of the valve's own behavior and from a study of the H and D curve. Mechanically the valve moves in exact proportion to the speech currents up to 90% modulation. Photographically, with the lamp current adjusted to give the proper density of the unmodulated track, 90% modulation can be used without driving the negative exposure into the under exposure regions. This modulation is only 1 db below full modulation, and for the occasional peaks which reach full modulation for a few thousandths of a second, the distortion is not detectible.

Let us assume that we have so regulated the recording that

FIGURE 6

At the left is a microphotograph of two frames from a recent picture, illustrating variable density sound track. The enlargement is to slightly over twice actual size. At the right is another example of variable density sound track.

only for occasional peaks is 100% modulation reached, and we have so controlled developments that the product of the positive and negative gammas is correct. It must be recognized that no amount of care in control of development will insure exact and unchanging value of gammas, either for negative record or for release prints. Some tolerances must be determined, fixing extremes of variation in development within which the sound quality is not noticeably affected.

In the reproduction of the sound record, four factors must be considered. These are: (1) the contrast laid down by the light valve and developed in the negative processing; (2) the contrast of positive development; (3) the optical conditions of reproduction; and (4) the electrical connection of the photocell to the reproducing amplifier. The Electrical Research Products, Inc., recommend that the development be checked by sensitometer strips measured in diffuse density. These are simply control measurements of the developing process. More detailed investigation shows that if the product of positive and negative gammas so determined equals unity, the sound record is satisfactory.

If the ideally perfect development is departed from by an amount which makes a difference of no more than 20% from unity as the product of the gammas, the resulting sound will be free from any distortion which can be detected. A departure of 20% from the ideal processing will result in a harmonic, for every frequency, whose amplitude is 5% of that of the fundamental. Experiments in telephone transmission have shown that distortion no greater than this is indistinguishable from distortionless transmission.

A corresponding variation in development of the picture would mean the difference between satisfactory screen projection and very harsh and dense prints on the one hand, or very thin and flat prints on the other, and it can be affirmed that the tolerance in the development of the sound track is considerably greater than that permissible for the picture.

The application of methods of sensitometric control results in a greater uniformity in the final product, with less wastage than when inspection during development is relied on. In this way the demands of the sound track have led to improvement in picture quality and worked a benefit instead of a hardship.

In *Fig. 6* are shown enlargements of the sound records obtained in variable density recording.

REPRODUCTION IN THE THEATRE

*S. K. WOLF**

The addition of sound to motion pictures more than doubled the amount of projection equipment necessary in the theatre. The images on the film are after all just translucent miniatures of what is to be shown on the screen. The sound source on the other hand is either a tiny scratch on a wax disc or an odd looking border along the film. In both cases a delicately elaborate arrangement of electrical machinery must intervene before the sound locked in the film or disc by the recording process can be brought to new life.

Three essential elements make up a reproducing system. They are:

(1) A pick up or reproducer.
(2) An amplifier.
(3) A loud speaker or receiver.

The function of the reproducer is to transform the sound record into electrical energy. The function of the amplifier is to magnify the infinitesimal electrical energy to the desired value. The function of the loud speaker is to transform this amplified electrical energy into acoustic energy and to distribute the acoustic energy or sound throughout the theatre or auditorium wherein it is being produced.

At the present time there are two types of sound recording used commercially. These are known as the film and the disc methods. The only essential difference between the systems used for reproducing film and disc records is in the pickup apparatus.

Fig. 1 is a schematic diagram showing the general layout of a sound reproducing system. You will note that provisions are made for reproducing both film and disc records, also that two machines are equipped, making in all four pickup devices. Obviously two machines are necessary to the continuity of the picture and sound reproduction. Provision is also made for select-

**Theatre Acoustics Engineer, Electrical Research Products, Inc.*

ing either the film or the disc pickup in Machine No. 1 or Machine No. 2. The next piece of apparatus in the circuit is the fader, the function of which is to control the volume of sound energy from this system. Following the fader is a switching panel

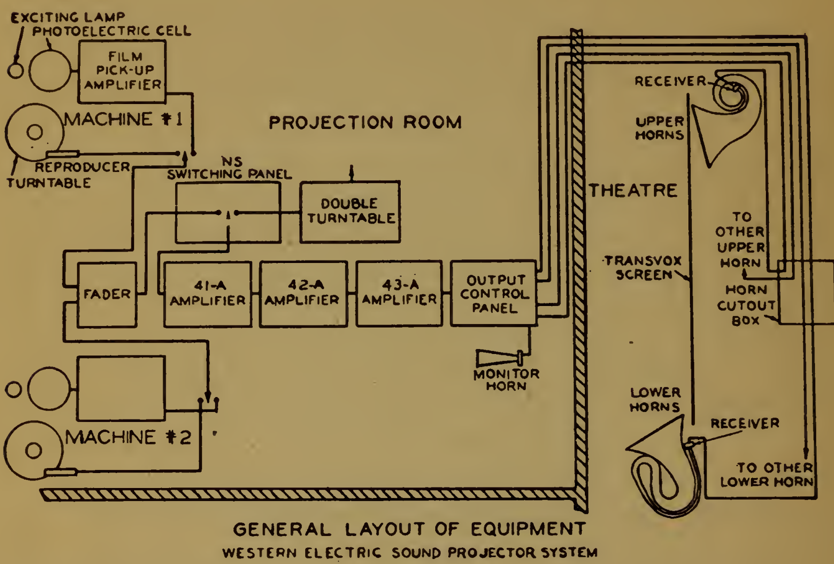

FIGURE 1

which permits use of non-synchronous reproduction as well as synchronous reproduction. After the switching panel are the amplifiers, a more detailed discussion of which will follow. The next element in the circuit is an output control panel, the function of which is to join the amplifying units with the loud speaker or receiver units. The receivers, as has been stated, serve to transform the amplified electric energy into acoustic or sound energy.

DISC REPRODUCER

In elaborating on the above description, let us discuss first the method known as disc reproduction. In disc reproduction a magnetic type of reproducer is used almost exclusively. This type of reproducer consists of a stylus connected to an armature of high permeability which is located within a small coil. In operation the stylus attached to the armature vibrates as a needle follows the grooves on the sound record. The movement of the armature between the poles of the magnet which surrounds the armature causes a variation in magnetic lines of flux and a voltage with corresponding variations is induced in the coil. This induced voltage is an electrical image of the sound record.

A section of this type of reproducer is shown in *Fig. 2*. This is a simple schematic diagram which will serve to illustrate the fundamental electric principle involved in the transformation of the sound record into an electric image of the record.

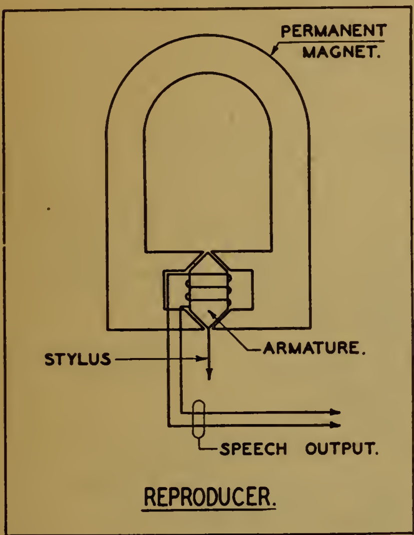

FIGURE 2

FILM REPRODUCER

With the optical or film record the situation is somewhat different. In this case the pressure variations caused by the sound have been transformed into a photographic image on the edge of the film. In the variable density film record this image takes the form of alternate light and dark lines running across that portion of the film reserved for the sound track. The separation between these lines depends upon the frequency of the sound while the contrast between the light and dark parts represents the loudness or intensity. In the variable area method the sound record is made by varying the width of the dark portion of the sound track. While with this variable area method the unmodulated track consists of a dark and a light band each one-half the width of the sound track, in the variable density method unmodulated track appears a uniform gray over the entire width.

In transforming the film record into electric energy the essential elements required for this transformation consist of an exciting lamp, a lens system and a photoelectric cell.

Fig. 3 is a schematic diagram of the sound head, parts of which will be described later in detail. It is evident from the relative location of apparatus as shown in *Fig. 3* that it is not feasible to print the film sound record directly beside the picture to which it applies. The sound track is printed approximately 15 inches in advance. This allows some slack between the sprocket which carries the picture with an intermittent motion before the picture projection lens and the sprocket which must carry the sound record with a uniform motion in front of the photoelectric cell. Special precautions are necessary to prevent vibrations and speed fluctuations, due to either a varying supply

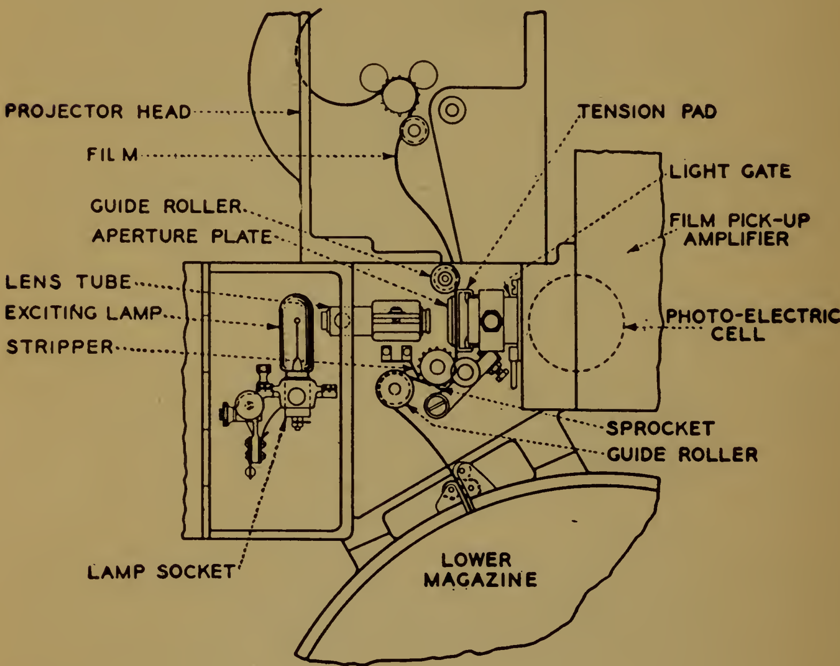

FIGURE 3

voltage or a varying load, from affecting the uniformity of rotation of the sound sprocket. The speed of the driving motor is automatically controlled as described in this paper under the heading Maintaining Synchronism. A mechanical device is also interposed between the sound sprocket and the rest of the moving equipment of the projector so that no abrupt change of speed will be transmitted to the sound sprocket.

Fig. 4 shows the exciting lamp and the lens relative to the film plane. The light from the exciting lamp is focussed on

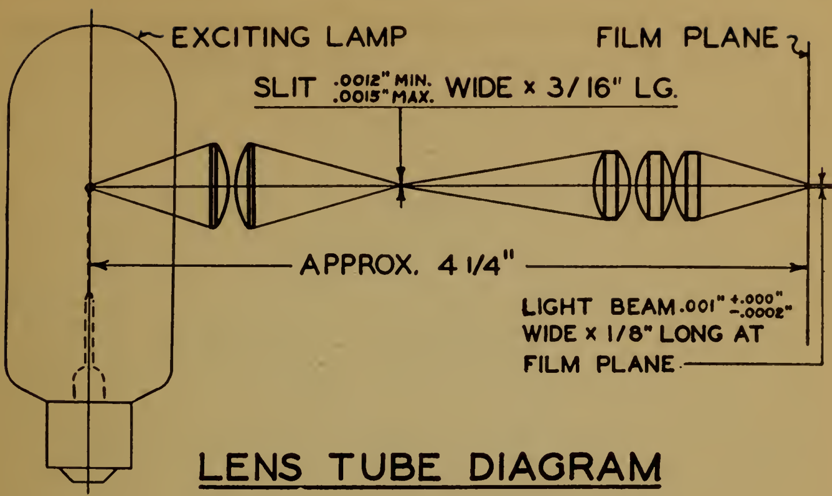

FIGURE 4

FIGURE 5

to the film as a very narrow beam one mil in width. It is necessary that this beam be very narrow as the highest reproducible frequency depends upon the speed of the film and the narrowness of the light beam falling on the sound track. The photoelectric cell on which the light falls after passing through the sound record is shown in *Fig. 5*.

Film reproduction is made possible through the use of this photoelectric cell or one having similar characteristics, that is, a cell capable of emitting elecrons at a rate proportional to the incident light within certain predetermined limits. This cell consists of two electrodes, one a photoactive metal and the other the sole function of which is that of an electric conductor. The photoactive metal most used for the purpose of sound reproduction is potassium. However, other alkali metals have been used. A polarizing voltage is placed across the terminals of the photoelectric cell through such a high resistance that in operation there is obtained from the cell a voltage across this resistance which is proportional to the incident light. This cell may be thought of simply as a resistance which varies directly with the quantity of light falling on the cell.

The photoelectric cell circuit is shown in *Fig. 6*. In a high impedance circuit such as this, local interference, sometimes termed static, is readily picked up and if not guarded against will produce serious distortion in reproduction.

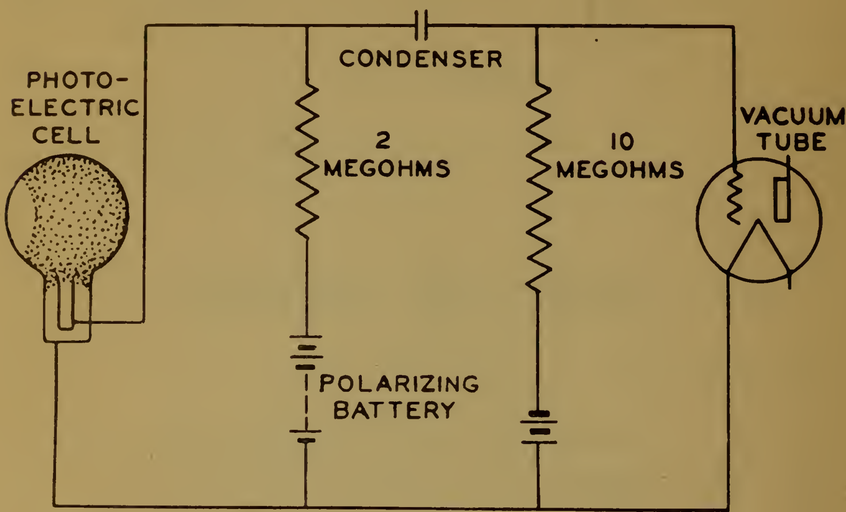

FIGURE 6

Since the energy level is so small, induced current may be appreciable in comparison to the sound currents themselves. In addition, there are other electrical effects which may create some distortion. Because of the low level of this power, it would be dangerous to transmit it any great distance before it has been amplified. Therefore, an amplifier (called a PEC amplifier) is placed immediately adjacent to the photoelectric cell circuit to amplify the power to a level at which it can be safely transmitted.

This amplifier increases the photoelectric cell output approximately 50 decibels or a power ratio of 100,000 to 1. The photoelectric cell and amplifier are encased in a heavy metal box which is fastened to the frame of the projector and the frame is carefully grounded. Further precautions are taken to insure against mechanical shock by carefully suspending the tubes of the amplifiers. The output of this amplifier is approximately the same as that of the magnetic reproducer used in disc reproduction. This will permit the remainder of the reproducing system to be used interchangeably between film and disc pickup. As shown in *Fig. 1* this change is facilitated by means of a transfer switch.

AMPLIFIERS

The energy produced by the pickup apparatus is not of sufficient magnitude to fill large spaces if it were transformed into acoustical energy. For that reason it is necessary to amplify the electric power of the pickup apparatus. The apparatus required for this amplification is a very important part of the equipment and must be carefully designed in order to insure against distortion of the original power obtained from the sound records.

Amplifiers have been designed in different sized units so that a selection of units may be obtained for the proper volume of sound for the widely varying size of theatres. In *Fig 7* are shown three of the amplifiers used in the Western Electric sound projection system. These amplifiers may be classified as Gain Amplifiers and Power Amplifiers.

The gain amplifier is used for the purpose of amplifying the small electric power obtained from the magnetic pick-up or from the photo-electric cell amplifier to a level suitable for operating the power amplifiers, which amplifiers are to drive directly the loud speakers.

In a house of about 1200 seats, that is about 175,000 cubic feet, it is only necessary to use the gain amplifier and one power amplifier. In houses up to 500,000 cubic feet or from 2000 to 3000 seats the gain and two power amplifiers are used. In houses such as Roxy's with 6000 seats and a milion cubic feet power amplifiers are added in multiple. In the new municipal auditorium at Philadelphia there are about 24 of these amplifiers.

The first or gain amplifier in the wall panel is identified as the 41-A unit in the Western Electric System. *Fig. 8* is a schematic diagram of the 41-A unit, a three-stage resistance coupled amplifier. The filaments in the tubes of this amplifier are connected in series and energized from a twelve volt battery supply drawing normally one-fourth of an ampere. The voltage supply for the plate circuit of this amplifier is obtained from the amplifier following, which has its own rectifier. This plate potential is obtained at 390 volts and is reduced by resistances placed in the plate circuit of each stage so that the voltage of the plate of each tube is kept at approximately 100 volts. In the circuit with these resistances are coils and condensers to smooth out the rectified voltage supplied to these sensitive first stages.

Even the slightest knock or jar of the tubes is converted into electrical impulses which are transmitted through the system

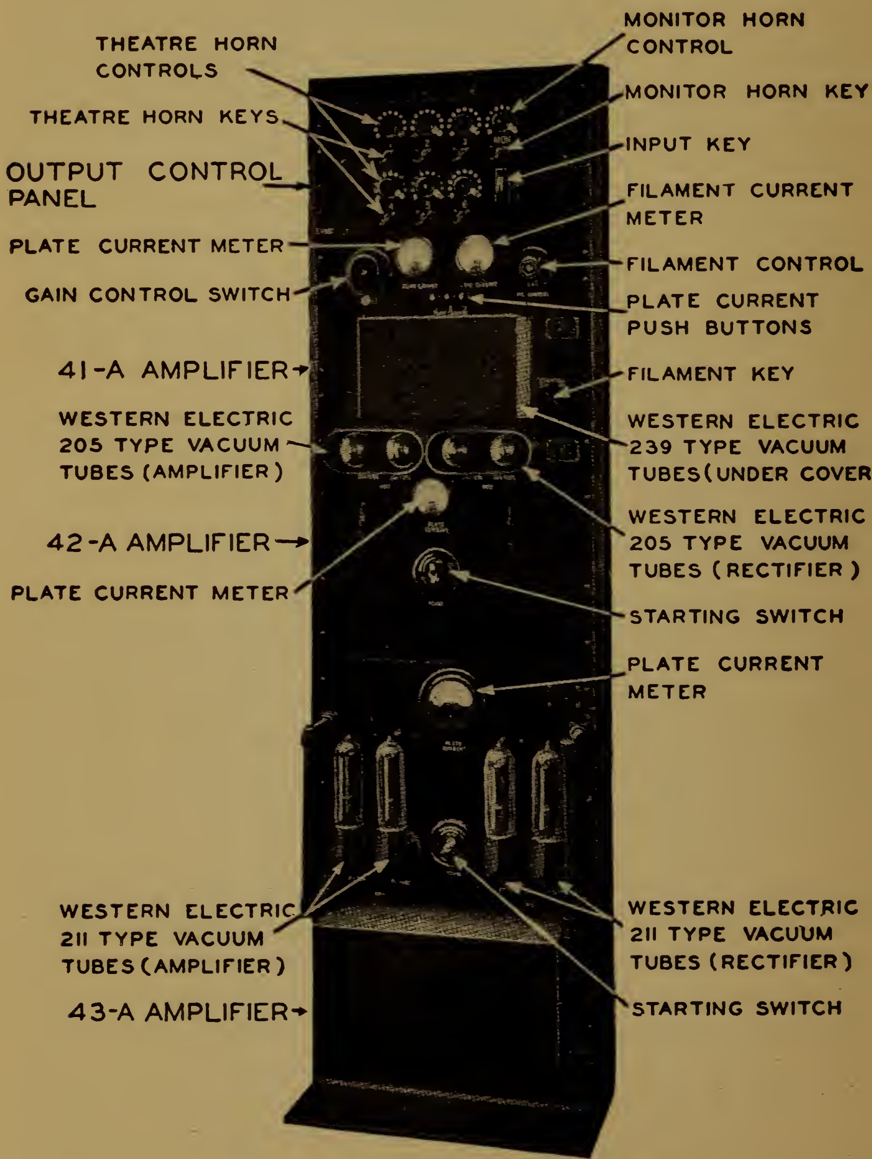

FIGURE 7

to the loud speakers where they appear as grating sounds. To prevent disturbances, the three vacuum tube sockets are mounted on a piece of sponge rubber which is fastened to a heavy steel plate and this plate is likewise suspended on a sponge rubber mounting. This suspension method is the mechanical analogue

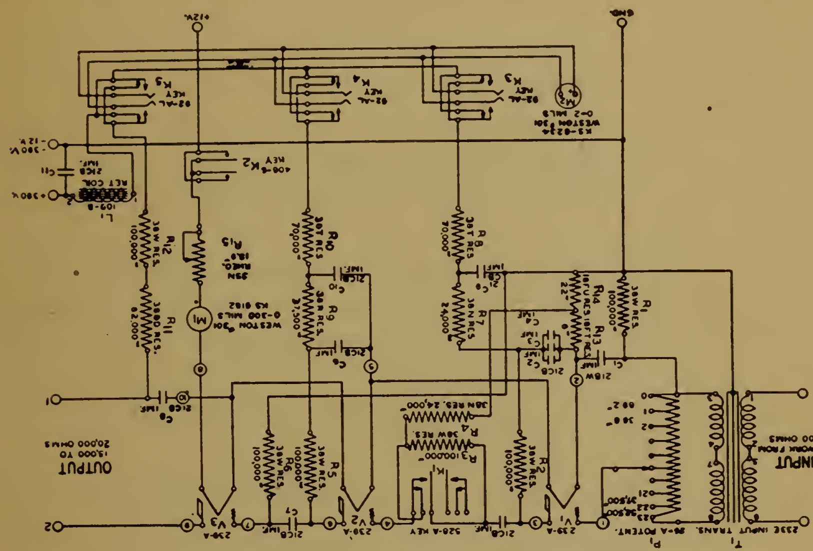

FIGURE 8

of the electric filters used to quiet the B supply on the amplifier systems, and represents a very efficient means of insulating the tubes from mechanical vibrations.

In order to control the gain or amplification of the system, a potentiometer is placed in the grid circuit of the first tube of the 41-A unit. This affords a gain control of 66 decibels in steps of three decibels each. A second means of controlling the gain of this amplifier is put in the grid circuit of the second tube. This gives an additional gain of 14 decibels. Gain controls could be put on the power amplfiers as well as on the 41-A unit, but this is not considered necessary. This gain control through the potentiometer should not be confused with the fader. The potentiometer is ordinarily set at the time of installation.

Each of the power amplifiers consists of a single stage circuit known as a "push pull" circuit. This is shown in *Fig. 9*. The power amplifiers operate entirely from alternating current. The 42-A and 43-A amplifiers shown in *Fig. 7* consume approximately 80 watts and 300 watts respectively. The amplifiers each make use of four tubes, two as amplifying tubes and two as rectifying tubes. The two rectifying tubes supply a plate voltage of 400 volts in the case of the 42-A amplifier and 800 volts in the case of the 43-A amplifier. No means are provided for controlling the gain of these amplifiers. These amplifiers are operated by means of a three-position snap switch which controls the A.C. supply. In starting the switch is turned to the first position which lights the filaments only. After they have had time to become heated, the switch is turned to the next position which supplies the plate voltage, making the amplifier ready for operation. This procedure in starting reduces the strain on the vacuum tubes which would occur if a high voltage were applied while the filaments were still cold.

The 42-A amplifier is capable of amplifying the power it receives approximately 325 times, which is equivalent to 25 decibels. The 43-A amplifier has a power amplification of approximately 36 times or 15 decibels. The 41-A, 42-A, 43-A combinations of amplifiers are capable of a power amplification of 100,000,000 times or 80 decibels.

For some houses, that is up to about 1200 seats, the 42-A amplifier will deliver sufficient power without distortion to get satisfactory results. In larger houses one or more 43-A amplifiers may be necessary, the number depending upon the size of the house.

LOUD SPEAKERS OR RECEIVERS

After the sound has been taken from the record and transferred into electrical power and amplified, it is then led to the loud speakers which convert it into sound. The types of receivers most used at the present time for talking picture work are the electro-dynamic coil type. There are many other types of receivers, but the above mentioned type has to date best fulfilled the requirements of talking pictures. The operations of these electro-dynamic receivers depend upon the force which exists between a coil of wire carrying a current and a surrounding uniform magnetic field. The magnitude and direction of this force depends upon the magnitude and direction of the current flowing in the coil, and upon the magnitude and direction of the uniform external magnetic field. Hence, as the speech current is applied to this coil it will tend to move in and out in such a manner as to follow the wave shape of the current, which completes the last step in recreating the original sound.

The receiver used with the Western Electric system is known as 555-W. It consists of a duralumin diaphragm. The diaphragm is made of a single piece of sheet aluminum alloy 0.002

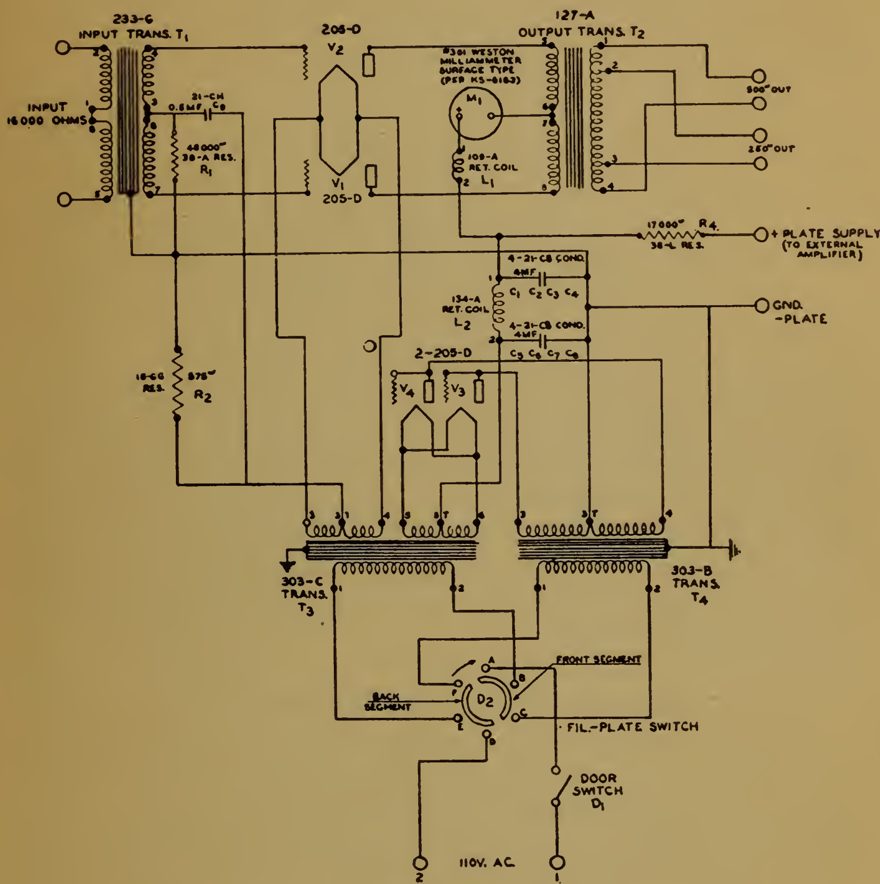

FIGURE 9

inches thick. This diaphragm (A) is shown in *Fig. 10.* To it is rigidly mounted a flat coil (B) of aluminum wire or ribbon 0.015 inches wide and 0.0002 inches thick, wound on edge. A thin coat of lacquer serves to insulate the turns from each other. It is the speech current circulating in this coil interacting with the magnetic field which forces the diaphragm in and out.

The receiver has been so constructed that the diaphragm vibrates as nearly like a rigid plunger as possible. This is accomplished by so shaping the center portion of the diaphragm that it is relatively stiff compared with the edge. Furthermore the coil which drives it is fastened around the outside of the stiffened central portion. The coil which is rigid and very light is made self-supporting. This form of mounting enables the coil to radiate heat readily, and therefore permits a large power input to the receiver without overheating.

The outstanding feature of this type of receiver is the high efficiency with which it converts electric energy into acoustic energy. In experimental models efficiencies as high as 50% have been realized. When you consider that a receiver of 100% efficiency would result in an increased sound intensity of three decibels, which is only a comfortably perceptible difference, it is not likely that much economy would be gained from higher efficiencies.

This type of receiver, when used, is attached to a horn which partially isolates a column of air from the surrounding medium. This column of air affords an acoustic coupling between the receiver and the space in which the sound is to be reproduced.

The horn is designed in such a way as to avoid interference between air waves as they pass through the chamber and the throat of the horn. The horn used is shown in *Fig. 11;* its design and construction is referred to technically as "exponential," which qualifies its shape.

MAINTAINING SYNCHRONISM

Synchronization between sound record and photographic record is an inherent requirement of sound pictures. In projection this is usually accomplished by mechanically coupling the picture projection machine with the sound recorder. Synchronization in itself is not sufficient, however, for there is still the problem of speed control.

Since musical pitch depends upon the frequency, it is necessary in reproducing music with fidelity of pitch, that the sound record be run at identically the same speed as that at which it was made. To accomplish this, some reproducing systems make use of a synchronous motor or certain types of induction motors whose speed characteristics are inherently constant under certain given conditions. However, variations of load, supply voltage and frequency may produce noticeable variations in pitch of the reproduced sound. A trained musical ear may detect pitch changes caused by speed variations greater than one-fifth of one per cent, particularly if these occur as fluctuations. The ordinary untrained ear may detect changes of less than one per cent. To further insure against such discernible changes in pitch, the Western Electric system makes use of a device known as a motor

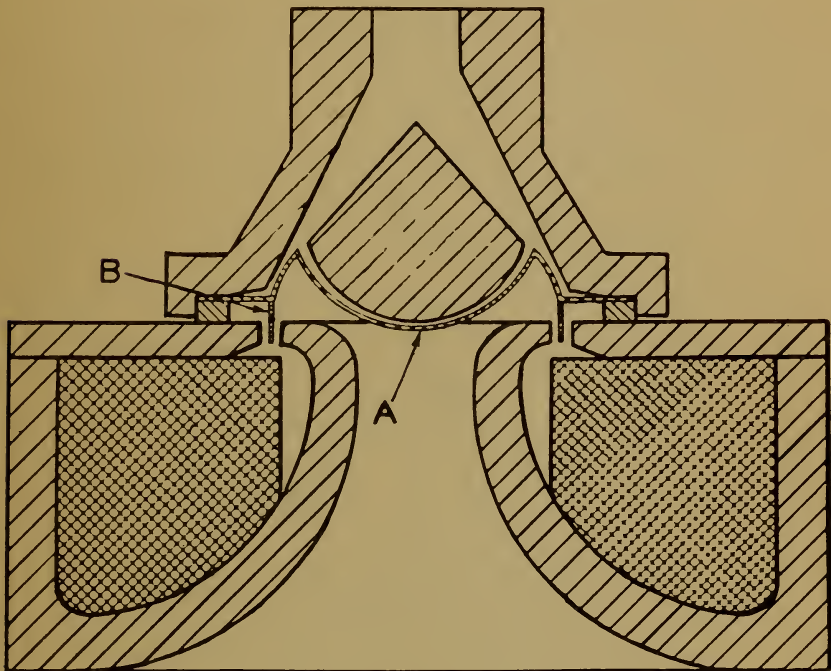

FIGURE 10

control box which maintains a motor speed regulation of one-tenth of one per cent, despite the ordinary variations of power supplies.

The motor control box furnishes an electric method of accurately controlling the motor speed. Its contents are somewhat elaborate and need not be described in detail for the purposes of this paper. A brief statement of its bridge circuit is given below:

Fig. 12 shows the governing system. The circuit is a special bridge circuit. One arm of the bridge is made up of a fixed inductance L and fixed condenser C in series. The valves of C and L are such that they tune the circuit at 720 cycles. Another arm of the bridge is pure resistance D with an impedance equal to the impedance of the capacity and inductance at 720 cycles, hence the ratio of the resistance D to C and L is unity at this frequency. The other two arms of the bridge circuit is the primary of

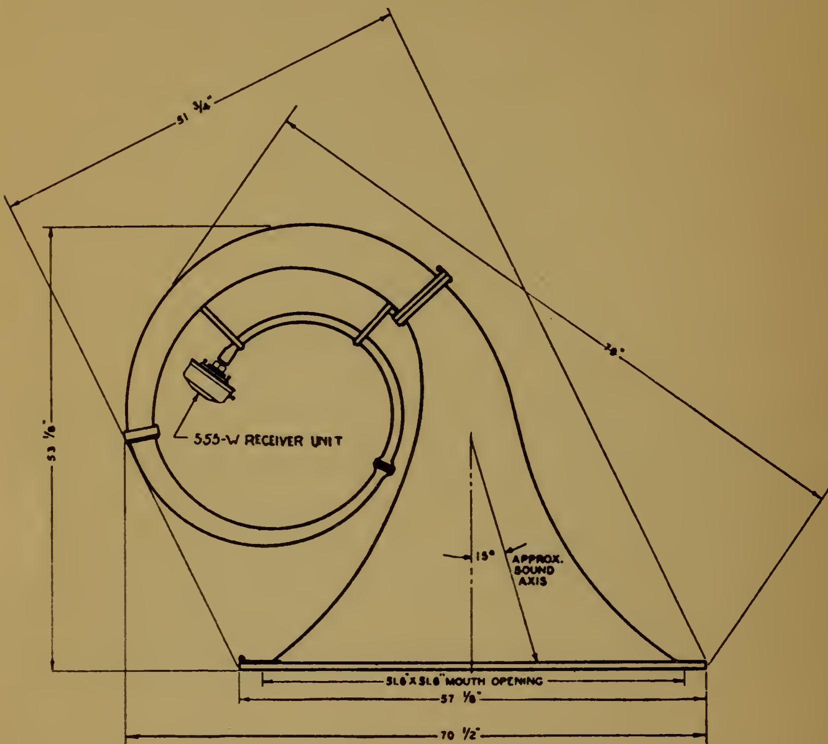

FIGURE 11

T_4 divided at its half tap. A 720 cycle potential is supplied from a small alternator when it is driven at 1200 R.P.M. This alternator is directly connected to the shaft of the main driving motor. When the speed is less than 1200 R.P.M. the applied potential across the bridge circuit is less than 720 cycles, hence the current in C is leading due to the predominance of the condenser, and if the frequency goes over 720 cycles, the current is lagging due to the predominance of inductance. Hence with a change of speed there is a change of 180° phase from less than 1200 R.P.M. to more than 1200 R.P.M. This shift of phase changes the potential of the grid of V_4 relative to the plate from negative to positive or vice versa, and thereby causes a relatively large change of plate current. This current flowing thru resistance R causes a correspondingly large change in the grid potentials of V_1 and V_2. Thus it is that a change of speed will either increase or decrease the current supply from V_1 and

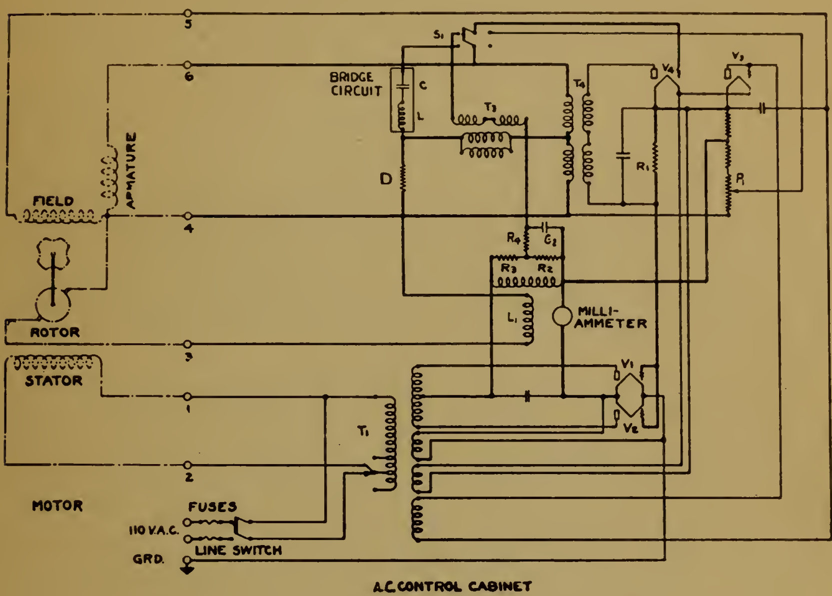

FIGURE 12

V_2. This current flows thru a winding which is on the same iron core as L_1. With increasing current from these two tubes, the magnetic flux in the iron core will increase to saturation and the impedance of L_1 decreases. The torque of the driving motor varies inversely with the impedance of the rotor circuit and hence with the impedance of L_1. Therefore, with an increase of current from V_1 and V_2 the reactance of L_1 decreases and the motor will speed up. Likewise a shift of phase of 180° will cause a lesser current from V_1 and V_2 and cause the reactance of L_1 to increase and the motor to slow up. To keep the motor speed more constant an additional network of R_2, R_3, R_4 and C_2 is added in such a manner that a change of potential across R_2 feeds back to the grid of V_4 and thereby gives the circuit additional regulation.

V_3 is a rectifier tube and furnishes direct current to the field of the 720 cycle generator.

By these means the motor speed is kept, under ordinary conditions, to within two-tenths of a per cent.

Switch S_1 when closed toward the right will make the motor run unregulated except for the hand adjusted potentiometer P_1 and the motor speed may be adjusted to whatever the operator might want.

VOLUME CONTROL

It is necessary to have some means of varying sound levels in theatres, first because of the variation in sound energy requirements in theatres, second because of the variation in levels of recorded sound, third because of the variation in the size of the audiences and fourth the desirability of level control during reproduction for the purpose of emphasis.

Most reproducing systems make use of two means of controlling sound levels. The first of these methods is the use of the gain control, with which the gain amplifier is equipped. The other is the use of an attenuating device known as the fader, which is usually connected electrically just ahead of the gain amplifier. The first method is generally used to adjust the amplifier system to the requirements of the particular theatre, while the second method is used by the operator during the show.

CAUSES OF DISTORTION AND FACTORS AFFECTING THE FIDELITY OF REPRODUCTION

Factors causing distortion in a reproducing system may be classified under three heads. First, those affecting the response at various frequencies (called frequency characteristics) ; second, those which cause the type of distortion known as non-linear; third, those which cause the addition of extraneous noises. In the case of the Western Electric system, if the apparatus is properly maintained and operated, the frequency characteristic is quite uniform from slightly below 60 cycles to somewhere above 5,000.

The type of distortion known as non-linear is the type which occurs when an amplifier or other part of the system is overworked. Such distortion may get into the reproduction in the theatre from one or more of the following causes: improper printing and developing of the sound track on the film or badly worn disc records, too low a charging potential for the photoelectric cells, too low filament currents or plate voltages on the amplifiers, insufficient magnetizing current on the receivers and other similar causes.

The extraneous noises which usually tend to be introduced by mechanical vibrations and interference from the power supply circuits, have been reduced to a minimum by the use of shielding and of both mechanical and electric filters in the design of the apparatus. Very little extraneous noise will be introduced in the film machine, provided the sprockets are kept in proper alignment and the film gate is kept clean.

Poor maintenance may result in development of bad contacts, faulty tubes and other similar troubles. These troubles usually result in causing one or more of the above types of distortion to be introduced into the reproduced sound.

PORTABLE SOUND PROJECTOR

Fig. 13 is a photograph of the Western Electric 202-A projector, a portable equipment.

This projector has a maximum throw of sixty feet. The maximum picture size is seven feet by eight feet. The apparatus is suitable for audiences up to 800.

In the upper left hand corner of *Fig. 13* may be seen the 1000 watt incandescent projecting lamp, with its mirror and condensing lens. Directly to the right is the projector with the orifice through which the beam is projected discernible under and adjacent to the lifting handle on the outside of the case. Directly under this is located the photoelectric cell and between this cell and the center of the case is located the sound gate, lens assembly and exciting lamp. Only one magazine is used. The two reels are placed on the same shaft with a spacer between them, the take up reel in the inner position. The film is threaded from the outside reel up through the outer feed sprocket in a large loop which passes over the top of the projector down through the light gate over the intermittent sprockett, then over the inner feed sprocket, down through the sound gate, over the sound sprocket and into the take up reel. It thus leaves the magazine and describes a loop through the apparatus back to the other reel in the same magazine. The preliminary amplifier is located behind the magazine in this illustration and consists of two stages mounted on a spring suspension. Means are provided to lock this suspension during transportation. The motor is seen in the lower left corner of the case. The drive is by

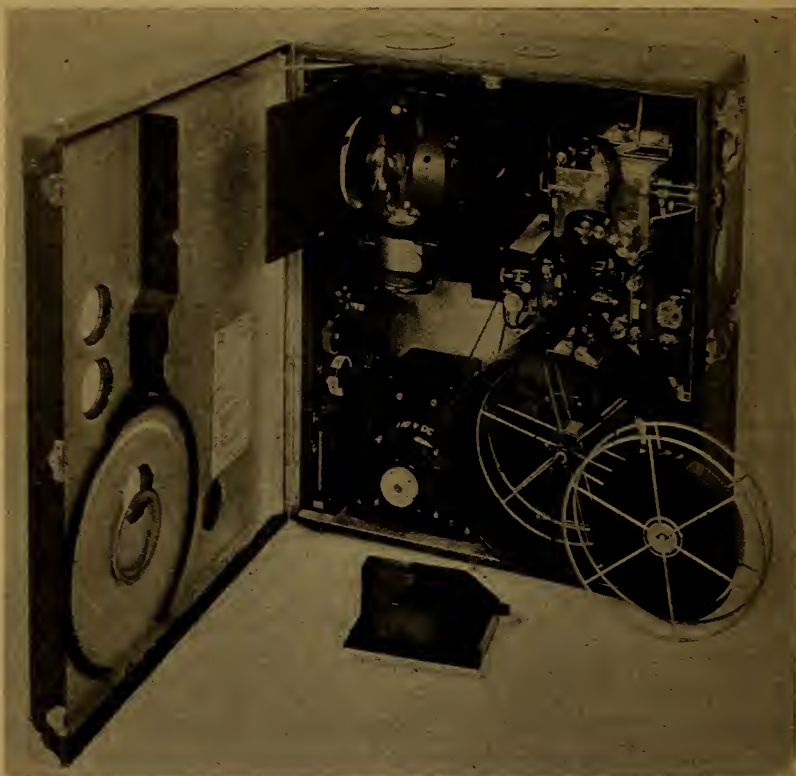

FIGURE 13

means of stepped pulleys and a round fabric belt to allow for adaptation for either 50 or 60 cycle current supply. To the left of the motor may be seen the control panel which is equipped with meters and rheostats for proper control of filament supply to exciting lamp and amplifier filaments, and with proper volume control.

The final amplifier is furnished in another trunk. This amplifier is a standard small size theatre equipment. A screen trunk is supplied with a collapsible rack to support the screen and a horn trunk furnishes the support for the horn in the proper relation to the screen.

REPRODUCTION IN THE THEATRE BY RCA PHOTOPHONE SYSTEM

*John O. Aalberg**

Perfect sound in a theatre is evidence of a succession of operations excellently done. The first operations have to do with the making of the record and are described elsewhere. The reproduction of the record in the theatre is its presentation to the ultimate auditors and its importance should not be overlooked. Sound apparatus, which must be expertly operated and maintained, has suddenly been added to the projectionists' cares. Some projectionists had the electrical and mechanical ability to cope with the problems that were of that nature but very few had the trained hearing which is necessary to adjust their reproducing systems as to the volume, balance, and allied problems that are essential to producing the real illusion of talking pictures. The training, or self-training, of these men presents a great problem to the industry, and the success of sound pictures depends on it.

Reproduction divides itself into two factors, one pertaining to the physical equipment and the other to the operation of it and handling of the show. All the present producers of commercial sound equipment have standardized their equipment as to speed, position of sound track, and relation of picture aperture to sound aperture so that any record produced can be reproduced on any theatre equipment.

Sound pickup from film is accomplished by adding a sound head to a standard projector (RCA Photophone System). See *Figs. 1, 2,* and *3.*

Such a device has in it mainly the optical system, photocell, constant speed sprocket, and a gate for guiding the film past the reproducing light beam. This beam is located so that the film distance from the picture aperture to it in the direction of film travel is nineteen and a half frames, or pictures. The printing distance between any picture frame and its corresponding sound

**Reproduction Supervisor, R-K-O Studios.*

is made twenty frames in some laboratories, nineteen in others. The reason for such a spacing is that it would obviously be impossible to have the reproducing accessories at the projector picture aperture.

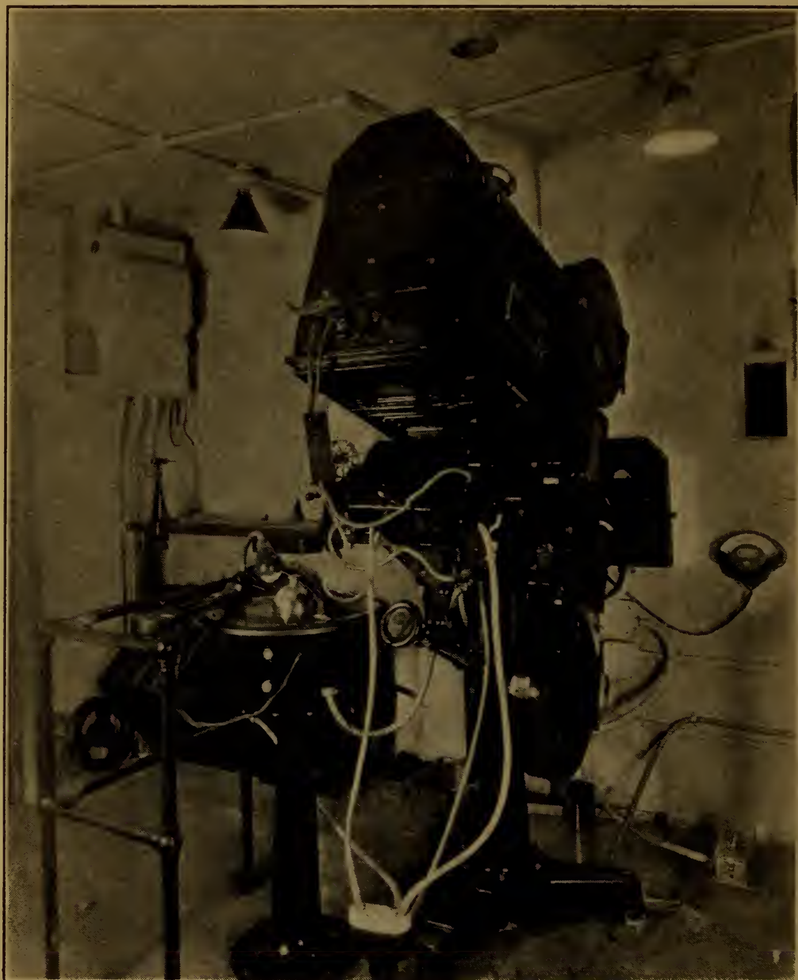

FIGURE 1

Simplex projector equipped with RCA Photophone sound head and disc attachment.

The optical system is focussed so that the reproducing light beam on the film is .085″ x .001″. The exciting lamp which illuminates the optical system is a small Mazda lamp, having a coiled filament suspended horizontally. Provisions for conveniently adjusting the position of this lamp are made because it is desirable that its position be such that the reproducing beam has the maximum amount of light possible in it.

When a film is run through the light beam, a beam of vary-

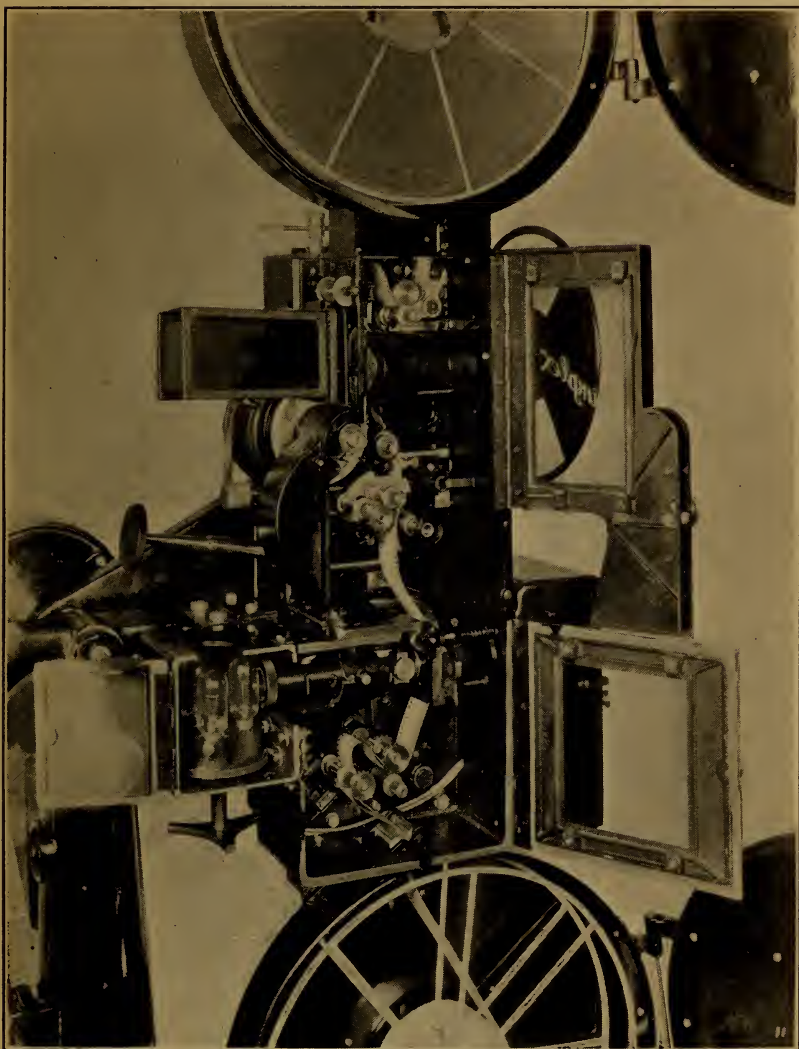

FIGURE 2

RCA Photophone sound head attached to Simplex Projector.

ing intensity falls upon the active part of the photocell. These variations are to be converted into electrical impulses. The RCA

Photocell's coating is caesium and a small amount of inert gas is added to the cell to increase sensitivity through ionization. The polarizing photoelectric cell voltage is supplied through the primary winding of a step-down transformer. The secondary of

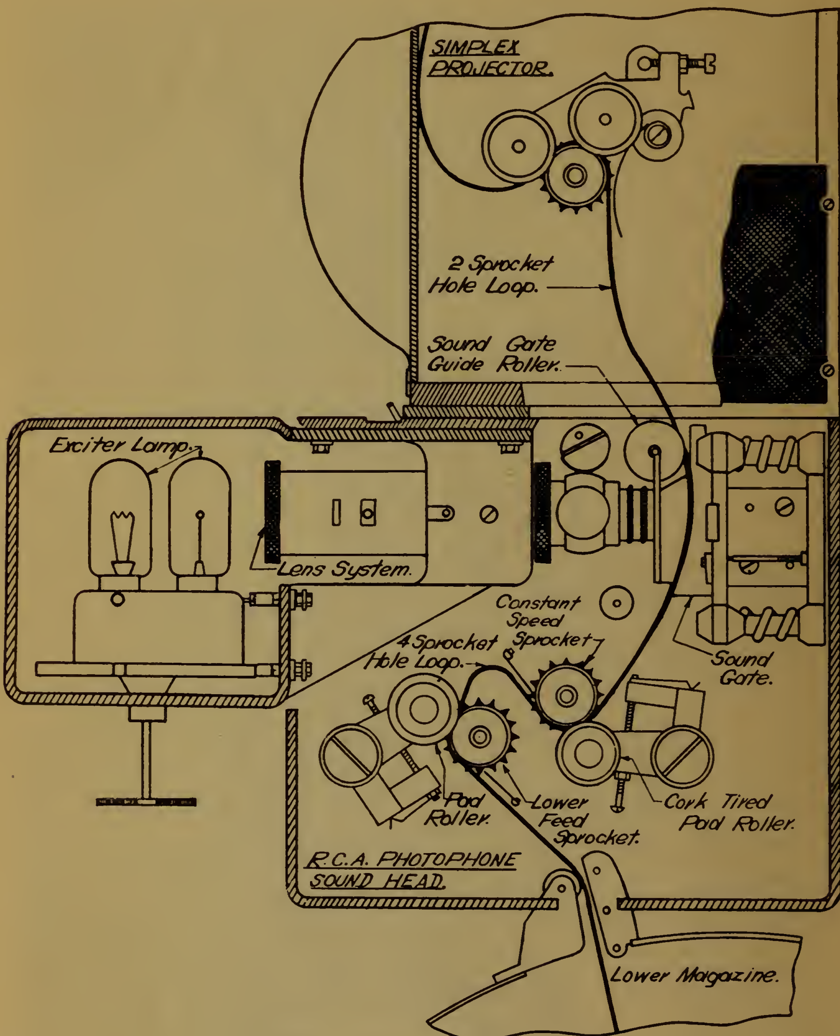

FIGURE 3

Diagram of RCA Photophone sound head showing film travel.

this transformer is connected through a fader to a step-up transformer at the amplifier. This arrangement eliminates the use of an amplifier on the projector and a source of possible

FIGURE 4
Rear view of RCA Photophone Type C amplifier. The top two amplifiers are voltage amplifiers and the lower two power.

trouble. For disc reproduction, a transfer switch is connected so that the photoelectric cell transformer is replaced by a magnetic pickup. This entire assembly is driven by a motor which will give constant 90 feet per minute film speed or 33⅓ r.p.m. record speed independent of varying line voltages and condition of load within operating limits and satisfies the requirement of reproduction that the film must pass the reproducing light beam at a constant velocity, that being the condition of film travel when the sound was photographed upon it.

The voltage amplifier consists of three stages push-pull UX 210 amplification which are battery operated. The voltage amplifier feeds an A.C. operated power amplifier capable of delivering 10 watts undistorted power. Its push-pull output consists of 2 UX 250 tubes. Such a power amplifier feeds four dynamic cones. Each power amplifier also has a rectox unit for supplying direct current to the fields of the cones connected to it, eliminating the use of horn batteries. For larger theatres, similar power units are paralleled, all being connected to the same voltage amplifier. On such larger installations, the voltage amplifier is duplicated for emergency use and is readily placed in service by throwing a switch. As each power amplifier is independent even to having its own speakers, on all installations of theatres seating over 750 all equipment is duplicated. A rack having two voltage amplifiers and two power amplifiers is shown in *Fig. 4*.

The loudspeaker used is the electro-dynamic cone. It consists of a parchment cone with a small coil affixed to its apex, which is slipped loosely around the core of a cylindrical electro-magnet excited by a direct current from its own power amplifier. When the signal current passes through the small coil, its magnetic reaction with the electro-magnet vibrates the parchment in synchronism with the signal current. This vibratory motion acts on a column of air and becomes sound. The cones are mounted on baffles aiding the reproduction of the lower frequencies. In reverberant houses these baffles are made directional.

Given a good commericial reproducing equipment, perfectly adjusted, and a theatre with good acoustics, we still have the variables of film condition and projection. The crackling noises we hear from a film record are known as ground noise. Some of it is recorded on the film, having been picked up when the record was taken or some added by faulty amplifiers. Much of it, however, is caused by dirt on the sound track in the form of small specks. This can be eliminated by cleaning the film. Additional noises may be added by improper patching. Whenever a patch is made it should be painted as shown in *Fig. 5*, so that the change in light entering the photoelectric cell is gradual, thereby causing little or no sound. With sound the changeover from reel to reel becomes very important so that no dialogue is lost. It is becoming practice in release prints to have a scene at the end and beginning of each reel in which no dialogue occurs so changeovers can easily be made without danger of losing dialogue. No sound feature should be shown without being rehearsed so that it may be checked for dirt, splices, changeovers, and volume. Many people differ on what volume should be, but in general it is agreed that the volume should be such that the persons on the screen speak at a level which gives the audience the illusion that the sound is coming from the action on the screen. For instance, we see a closeup of an actor speaking and, if the sound is too weak, there is no illusion because the sound seems to be coming from a point far behind the screen. Conversely, if the voice of a person back in a long shot is played too loudly, the illusion is also spoiled. Volume should be raised for a crowded theatre over what it is for a half filled one.

The sound track on film is about .100 inches wide and re-

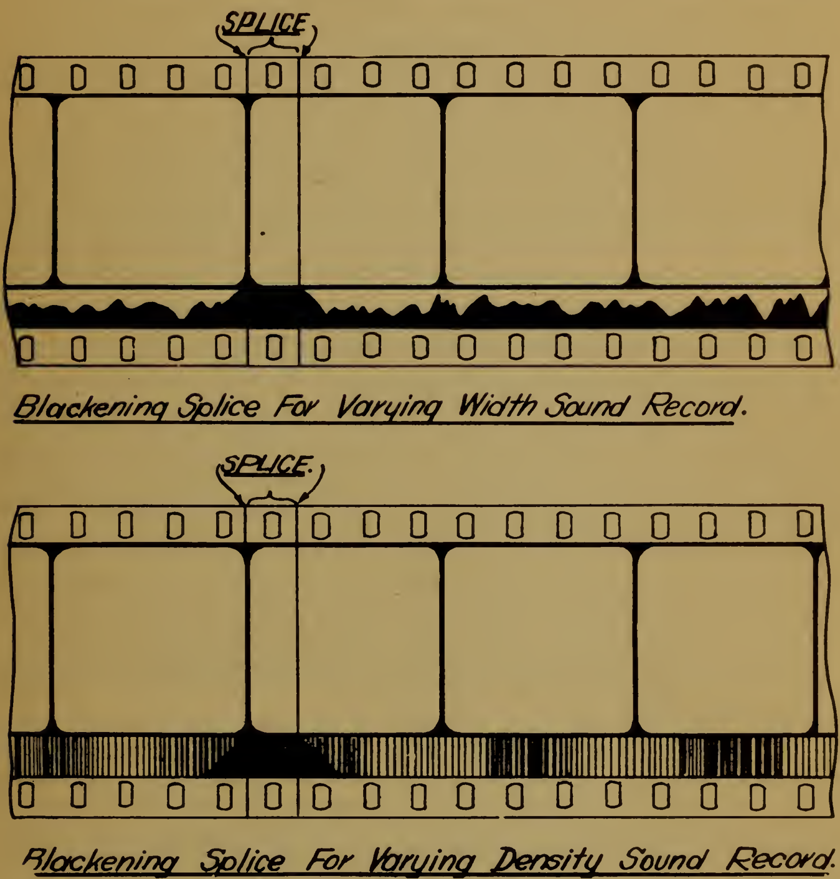

FIGURE 5

Accepted practice for blackening splices.

places that amount of picture. The old ratio of picture height to width was 3 to 4, a frame being approximately ¾″ x 1″. Removing .100 inches in width leaves the picture nearly square. Theatres seem to prefer the 3 x 4 picture for artistic reasons and to secure interchangeability with films of the old standard size by merely changing lenses. It has become the practice in many theatres, therefore, to use an aperture which restores the 3 x 4 proportion by cutting ten percent from the height of the picture. To meet this condition nearly all cameramen are now composing their pictures with extra head room. As theatres using the smaller aperture also use a shorter focal length lens to make the picture as large as it was with a standard aperture the film grain, dirt, scratches and photographic defects become slightly more apparent with the greater magnification. Pictures produced to be accompanied by sound on disc only are generally photographed and projected the same size as silent pictures.

A reproducing system which is not properly adjusted will, of course, spoil any record. It is essential that all the vacuum tubes operate at their proper voltages. The adjustment of the light beam which falls on the photoelectric cell is important. Should this beam be wider than .001 inches, a loss of high frequencies results. In case the beam falls to one side of the track it will pass through the sprocket holes and give a 96 cycle hum, or, if the other way, it will reproduce a click for each picture frame line passing it. On variable area sound track a light beam off position will cause distortion because it will only be covering part of the sound modulation. In variable density no similar distortion occurs from this source but the volume falls off. The pressure pad which holds the film taut as it passes the reproducing light beam must apply just the right amount of pressure. Too much is likely to produce flutter, which reveals itself by making voices gurgle. Too little pressure will allow the film to move in and out of focus causing loss of high frequency response and articulation.

Anything that causes the film to pass the light beam jerkily produces flutter. Prominent among the causes are projectors driven through unevenly cut gears or having poorly adjusted intermittent movements. The degree of film shrinkage and condition of sprockets and sprocket holes also affects flutter.

The industry's problem is to get natural and intelligible sound in theatres. Each craft must do its best for the record as it evolves from sound to input to sound output and only as each craft realizes the problems of the others can perfect reproduction be hoped for.

TECHNIC OF RECORDING CONTROL FOR SOUND PICTURES

*J. P. Maxfield**

The purpose of acoustic control in recording is to make the sound record so correlate with the picture, that the whole performance becomes pleasing to listen to and easy to understand. It has been found that this result is obtained when the recording is so conducted that the voice, coming from the horn, appears to follow the speaker wherever he or she may go in the set, i.e. when an illusion of reality is obtained.

Before considering this matter in detail, there are one or two preliminary points to be taken up. The first has to do with the nature of the material to be covered by this paper, which is distinctly of a practical nature rather than a theoretical. Any theory which may be discussed is in the form of an explanation of why the technic operates as it does, the technic itself having been successfully used throughout several commercial productions.

The second preliminary matter is a brief review of some of the material, which has been mentioned previously from a theoretical standpoint, and which should now be discussed from the point of view of its practical use in the making of talking pictures.

Dr. Knudsen discussed the curves shown in *Fig. 1.* The discussion here will deal only with the one marked E(n). The vertical ordinate represents energy of speech, corresponding to the frequencies shown by the abscissa. Fortunately for those who have to operate the recording equipment, the high maximum occurring at approximately 200 cycles does not indicate maximum intensity or the maximum amplitude, which is obtained at that frequency. The data represented by the curve was obtained in such a way, that the energy shown includes not only the amplitude or the intensity which occurs at any given frequency, but also includes how often energy of that frequency

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occurs in speech and also how long it is sustained when it does occur. The high maximum is brought about mainly by the fundamental tones of the voice. Since the fundamental occurs in all of the vowel sounds, and since the vowel sounds are gen-

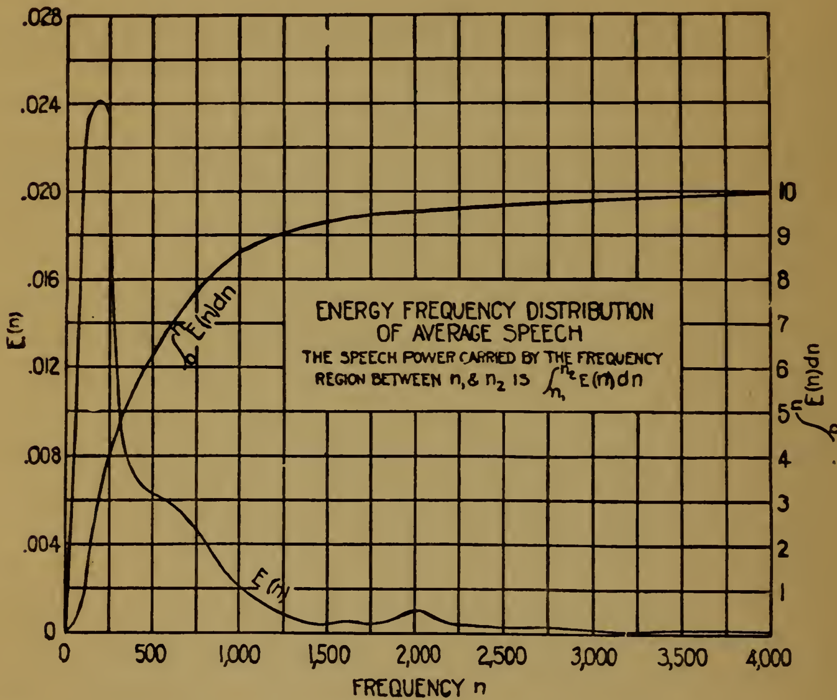

FIGURE 1

erally held longer than the other speech sounds, it is seen that a large contribution to this high maximum is brought about by the time factor rather than the intensity factor.

Dr. Knudsen also discussed the curve shown in *Fig. 2,* in which the ordinate shown at the right hand of the curve, represents sensation units expressed in decibels, while the abscissas represent frequency or pitch. The lower line of the curve represents the threshold of audibility, while the upper line represents the intensity at which the sound becomes physically painful. The useful range between these two curves is of the order of 100 to 120 sensation units. It would appear at first sight, that the recording system, which covers a range of approximately 40 sensation units, would be totally inadequate. However, there are some features which limit the practical use of this whole range, other than those that reside in the recording system: First, the average noise in a theatre from the venti-

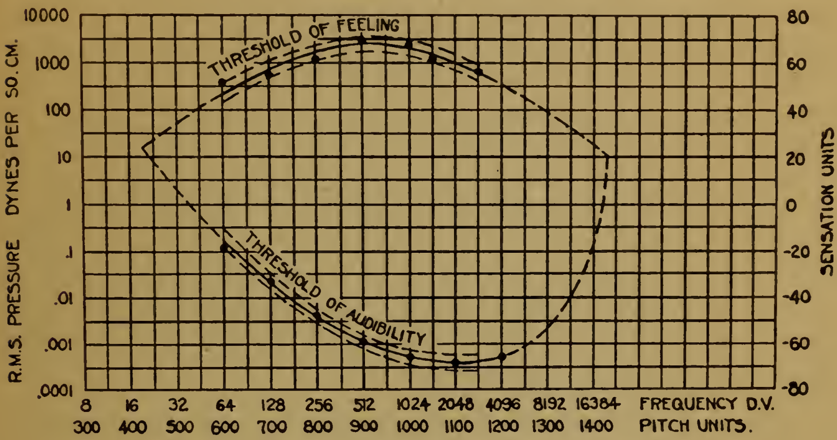

FIGURE 2

lators, audience, etc., is seldom less than 30 sensation units above minimum audibility, and is frequently as much as 40. It is, therefore, useless to reproduce in the theatre any sounds less than 40 sensation units above minimum audibility, as they would become lost in this noise. Second, the upper 30 or more sensation units represent sound intensities of the magnitudes encountered from the firing of big guns, large explosions and other uncomfortably loud sounds.

Therefore, except for the few isolated cases, where records are being made of such explosions, the practical useful ranging has been reduced by 70 sensation units, and there remains only 30 to 50 to be accommodated ordinarily. The Western Electric recording system can easily accommodate 30, and when properly maintained and operated, can accommodate 40. When it is considered that the difference in loudness, between a stage whisper and a very loud shout is about 30 sensation units, it will be seen that the limits of the system do not ordinarily handicap recording.

In the terms of the movies, *Fig. 3* is a close-up of the curve shown in *Fig. 2,* with four additional curves added. These four curves represent the lines of constant loudness of 20, 40, 60 and

80 loudness units above minimum audibility. The top and bottom lines are identical with the top and bottom lines respectively, of the curves in *Fig. 2*. This curve indicates that in going from loudness 20 to 40, it is necessary to increase the gain of the amplifying system 20 db for the frequencies lying in the middle region. On the other hand, in order to go from a loudness 20 to loudness 40, at the low frequencies, say around 60, it is only necessary to go 6 to 8 db. However, loudness is mainly interpreted by the middle region. If, therefore, a sound which was originally made at loudness 20 were reproduced by increasing the intensity by all its components by 20 db, it is obvious that the loudness in the bass would lie slightly above the curve representing a loudness of 60, i.e. more than 20 loudness units too high. Such reproduction would sound over-bassed or "heavy." This is one of the reasons why the human voice sounds heavy when reproduced at a level considerably higher than that at which the person actually spoke.

This effect is inherent in the ear, and as the recording becomes more and more perfect, the loudness level, at which music or speech is reproduced, becomes more and more important. This ends the preliminary review.

The technic of acoustic control is based on letting the camera be the eye and the microphone be the ear of an imaginary person viewing the scene. It might be interesting, therefore, to consider briefly how a person observes, that is, how he sees and hears what is taking place around him.

When a person is viewing a real scene in real life, he is viewing it with lenses—that is, the eyes, and pickup devices—that is, the ears, which are in a fixed relationship, one to the other. This observer is equipped with two eyes and two ears. The two eyes enable him to appreciate distance or depth with much more facility than would be possible with one eye, while the two ears enable him to appreciate direction and perhaps, to a slight extent, depth where sound is concerned. The point of importance, however, is the fact that the eyes and ears maintain a fixed relationship to one another.

The method by which direction is determined with either one or two eyes is obvious and need not be discussed. The factors which enter into the appreciation of depths or perspective of sound are the ones of interest here.

It is probable that the most important factor, particularly where monaural hearing is concerned, is that which deals with the relative change in loudness of the direct and reflected sound. Since the intensity of the reflected sound varies relatively little

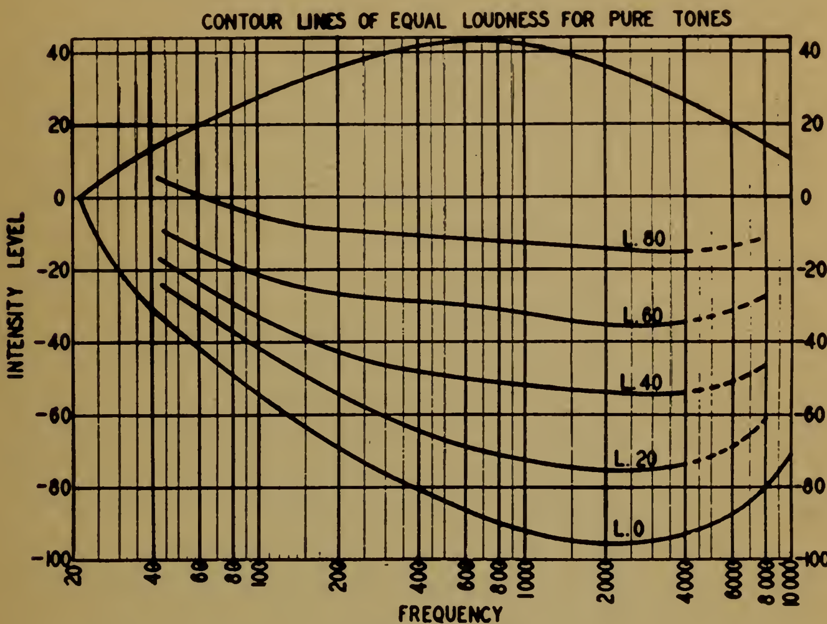

FIGURE 3

from place to place in a room, while the direct sound from the source to the pickup device varies quite rapidly with its distance, the ratio of the intensity of the direct to the reflected sound also varies considerably. Hence, as a source of sound, such as a person speaking, recedes from the microphone, the loudness of the voice appears to decrease slightly while the reverberation appears to increase materially. With binaural listening, this is unconsciously interpreted as distance. It has been found that this effect, when properly controlled, is also interpreted as distance with monaural listening.

In the case of the talking pictures, the camera has only one eye, or lens, and the recording system has only one ear or pickup device. Consequently those effects, which were brought about by the binocular seeing and by binaural hearing, cannot be made use of. Long experience with the photography has enabled the cameraman to create a part of the depth illusion by the proper choice of the focal length of the lens used, and by the proper type of lighting. Fortunately, for the acoustic engineer, the impression of depth depends upon factors which are almost as effective with monaural as with binaural listening; namely, the change in the ratio of the intensity of the direct sound to the reverberation present.

The loss of direction, brought about by the use of one ear only, causes some rather unexpected results. When two ears are used, a person has the ability to consciously pay attention to sounds coming from a given direction, to the partial exclusion of sounds coming from other directions. With the loss of the sense of direction, which accompanies the use of monaural hearing, this conscious discrimination becomes much more difficult, and the incidental noises occurring in a scene, as well as any reverberation which may be present, are apparently increased to such an extent that they unduly intrude themselves on the hearer's notice. It is, therefore, necessary to hold the reverberation, including these noises, down to a lower loudness than normal, if a scene recorded monaurally is to satisfactorily create the illusion of reality, when listened to binaurally.

This apparent increase in reverberation and incidental noises may easily be heard, by completely stopping up one ear and listening with the other only. It is easier to detect the effect in a room, where the incidental noises are fairly loud, and where the amount of damping is slightly less than in the normal living room.

Since it is possible to create the illusion of depth or distance in both the visual and audible parts of the talking picture, it is necessary that the amount by which the voice appears to move forward and backward in the set, should correspond with the amount the image appears to move. The amount by which the voice appears to move forward and backward in the set, depends upon the amount of reverberation present, and upon the relative distance of the microphone from the foreground and background action. In general, the more reverberation present, or the further the microphone from the source of sound, the greater is the apparent distance of the voice from the near foreground. It has also been found by experience, that if the conditions have been made correct to obtain this illusion, then the voice or sound also appears to follow the picture across the screen.

There is one important difference between the imaginary observer in the scene and the taking of a talking picture. The real observer maintains his pickup device, namely ears, at the same distance from the scene as his lenses, that is eyes. This is not necessarily the case with the talking pictures, as the cameraman may at will, use lenses of different focal lengths, whereas the observer cannot change the focal length of his eyes beyond that amount required to accommodate focus. The use of long focus lenses by the cameraman is equivalent to a means of bringing distant action into the near foreground. When such action is brought into the near foreground by the use of the closeup, it is also necessary to pull the sound up, so that it appears to be coming from a similar distance, that is from the image on the screen.

There is one other point to be kept in mind regarding the analogy between the imaginary observer and the talking picture equipment. If a speaker in the scene walks away from the imaginary observer, he walks away from both his eyes and his ears. It is, therefore, necessary to place the microphone in the same approximate direction from the action as the camera, in order that the speaker shall approach the microphone when approaching the camera and vice versa.

In view of the above, it cannot be too strongly stressed that it is important to use one microphone only for a given camera position. Naturally if the camera position changes during the scene, the microphone position should change accordingly, so that the proper relation between the ear and eye is maintained. The insistance on this requirement on one of the early pictures made, led some humorist to call this technic "The Trail of the Lonesome Mike." It should be noted from previous paragraphs; one microphone position only for one camera position. There are some cases involving complicated setups, where closeups and long shots are being attempted simultaneously, where more than one microphone may be legitimately in the set at one time, but only one of them should be on at any given time. The one that is on, naturally should correspond with the camera whose picture is to be used in the final cut. This use of closeup and long shot simultaneously, requires a knowledge of how the scene is going to be cut, and should, therefore, be avoided if there is any doubt about the cutting.

During one of the first pictures that was made with this technic, the studio people were coaxed into making the sets with sufficient reverberation to produce the depth effect. The set in question was about 25 or 30 feet wide and some 35 feet long and

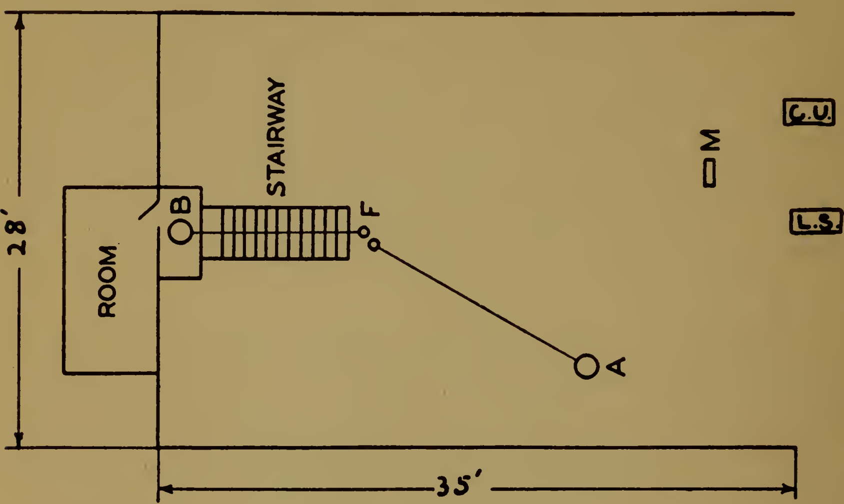

FIGURE 4

approximately 24 feet high, as shown in *Fig. 4.* It represented a large hall in an old fashioned European home, and there was an entrance onto a stairway from a second story room at the back of the set. The dialogue was started in the middle foreground by a man at A, and then a young lady came out of the second story room at B, and said a few lines, the dialogue continuing until both people were at the foot of the stairs at F, midway back in the set. The studio people insisted on making a closeup and a long shot simultaneously, and as the long shot covered a considerable angle, it was impossible to get a microphone into the scene sufficiently near the young lady to take care of a sound track for her closeup at entrance. When the rushes were shown in the review room, the first to come thru was the long shot, and the result was exceedingly good, the voice appearing to come from the mouths of the speakers. The second rush showed the long shot scene with the closeup of the young lady cut in at the proper place. This picture, however, was coupled up with the only sound track available, namely, the long shot sound track. Of the five people in the review room, three unconsciously moved their heads to one side to see around the girl, in order to find out who was speaking in the room behind her. The effect was so disconcerting that it was necessary to retake the closeup with its own sound track.

Since the interpretation of distance by the microphone de-

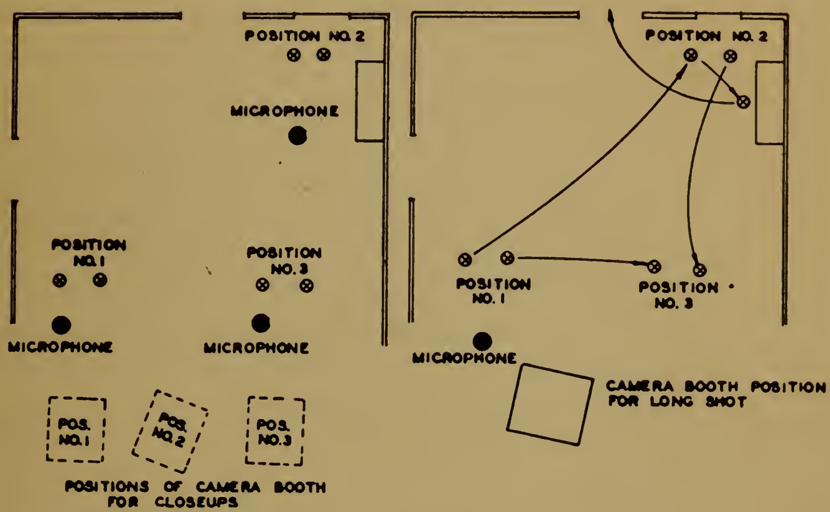

FIGURE 5

pends upon the acoustic properties of the set, there is only one microphone distance at which the proper sound distance will be obtained. This is analogous to limiting the cameraman to a single lens for his camera. Hence, when a change is made to a long focus lens, it is necessary to move the microphone nearer the scene than was necessary for the shorter focal length.

It is now time to consider how much the microphone must be moved when the lens is changed. With sets built in the manner to be described later, the microphone should be as far away from the foreground action as it would be necessary to place a 30 to 35 millimeter lens, in order to obtain the same sized image as will be obtained with the long focus closeup lens actually in use.

Fortunately, if the difference in focal length between two cameras used simultaneously is not too great, the ears' interpretation of the depth effect is not sufficiently accurate to cause any trouble. It is, therefore, possible to use a 35 to 40 millimeter lens simultaneously with a two inch lens without difficulty, provided the depth of action is not over 12 to 15 feet. In scenes of ordinary living rooms, no trouble would be caused by this arrangement, provided the two inch lens is not brought much closer to the subject than the shorter focus one.

Figure 5 shows two views of the same set and the same action, the right hand section indicating the situation for a long shot, while the left hand section indicates the camera and microphone positions for close-ups of each of the three dialogues, namely, those at positions 1, 2 and 3 respectively. The long shot was made with a 35 millimeter lens, whereas the close-up cameras were equipped as follows: Camera for position 1, 4″, for position 2, 6″ and for position 3, 4″. The corresponding microphones are shown. It will be noted in the close-up section that three microphones were in use, but it should be further noted that only one was used at any one time. That is, when the dialogue was taking place in position 1, its microphone was on, and similarly for positions 2 and 3. The action occurring during the transition from positions 1 to 2, and 2 to 3, was taken care of by the long shot made under the conditions shown in the right hand section.

The next major item deals with the design of the set, with a view to obtaining the proper conditions for the acoustic perspective. When a person listens with two ears in a real scene, he is able by his sense of direction, to pay attention to the sound coming directly from the speaker, to the partial exclusion of the reflected sound and incidental noises coming from all around him. However, with this sense of direction destroyed by the use of one ear only, he is no longer able to make this discrimination, and the reflected sounds, that is, the reverberation and incidental noises, appear to increase in intensity. It is necessary, therefore, to insure that the set have less reverberation than would have been actually present in the real scene. It has been found by experience, that if the walls of a three walled set are built of materials having similar acoustic properties to those depicted in the real scene, that the absence of the ceiling and end wall provide sufficient damping to render the acoustics suitable for recording. This of course assumes that the sound stage is dead, or that the set is built out of doors. In practice, however, it would be both inconvenient and expensive to build the walls of a set of the materials that would really have been used had the scene been a real one. It is necessary, therefore, to use imitations. These substitutes should imitate acoustically the real materials as nearly as possible, and in particular should be braced sufficiently so that they do not tend to materially partake of the vibrations set up in the air by the sound.

When a set has been designed in this manner, experience has shown that the incidental noises sound more realistic and convincing, and that they may usually be recorded at the time the original scene is taken. In one picture, on which this technic was used, some dramatic scenes occurred which were to be intensified by a period of sudden silence. In order to accentuate the silence, the ticking of a clock, situated on the rear wall of the set, was to be the only sound heard. The question was immediately asked what should be used to imitate the clock. The obvious answer is the clock, since it is difficult to get any other instrument to sound more like the clock than the clock does. The scene was recorded, using the clock as the source of sound, with the microphone in the normal dialogue position for the action, and a very successful sound record resulted.

In view of the stress that has been laid on the necessity of sets having more sound reflection than those previously in use, it might be of interest to consider why some of the sets of the past have given what is commonly called a "tubby" quality. There are two ways in which a set can cause the sound to persist in it for a short time after the source has stopped. The first of these methods is by reflection of sound from the walls and floors and this method is the only one which should be active to any extent. The second method is by a diaphragm action of the walls. In this case the sound sets the walls into vibration, and they continue to vibrate for a short time, thereby causing sound after the original source has stopped. This type of "hang-over" usually has a decided frequency characteristic and is highly objectionable.

In the earlier sets, the spacing of the studding, and other supports for the set-wall material, was so great that the natural periods of the wall sections occurred in the same frequency region as the fundamental tones of the average male voice. This resulted in an accentuation of the low pitched frequencies of the voice, without a corresponding accentuation of the higher frequencies, which higher frequencies are responsible for both the crispness and articulation. To make matters still worse, where the sets were heavily draped, the damping material usually absorbed these high frequencies more efficiently than the lower ones.

With these early sets, which were designed in such a manner that they accentuated the low frequencies, and removed, by absorption, the high frequencies, it was practically impossible to record highly intelligible speech unless the speaker faced approximately toward the microphone. With the liver sets recommended, if the high frequencies, particularly those which carry the hissing sounds, fail to reach the microphone directly from the speaker's lips, they do succeed in reaching it by reflection from the walls of the set. It is, therefore, possible with these sets to record intelligible speech, where the speaker is facing directly away from the microphone position.

One interesting fact in connection with the use of the technic described is that the pictures recorded by it, are not run too loud in the theater. This probably results from the fact that the reproduction is easily and comfortably understandable at the back of the theater, without excessive loudness.

There is one more important point to stress. Except under very unusual conditions, the mixer dials should be set at the beginning of the take and not touched thereafter. In other words, the record should be made with the volume ranges demanded by the scene being depicted. This rule applies to more than 90% of the recording required for pictures.

Any one who has done much mixing will realize the discomfort of complying with this rule, because of the natural tendency to twist the dials. Someone has facetiously nicknamed this tendency "mixer's itch." Probably the best way to overcome it is to continue to twist the dials, but limit the amount of twisting to about 3 db. Since 3 db is scarcely noticeable to the ear, it does no damage to the overall artistic result and is therefore permissible. After the mixer has become accustomed to limiting the twisting to 3 db, he can then remember that since 3 db is hardly noticeable to the ear, this amount of mixing not only does no harm, but also does no good and therefore is unnecessary. In view of the fact that most of the recording does not require mixer manipulation, it seems unfortunate that it is necessary to appear to lay any stress on the exceptions by enumerating a few. However, it is necessary from certain practical considerations to occasionally control the volume during recording. An instance of this is as follows: when two actors, playing

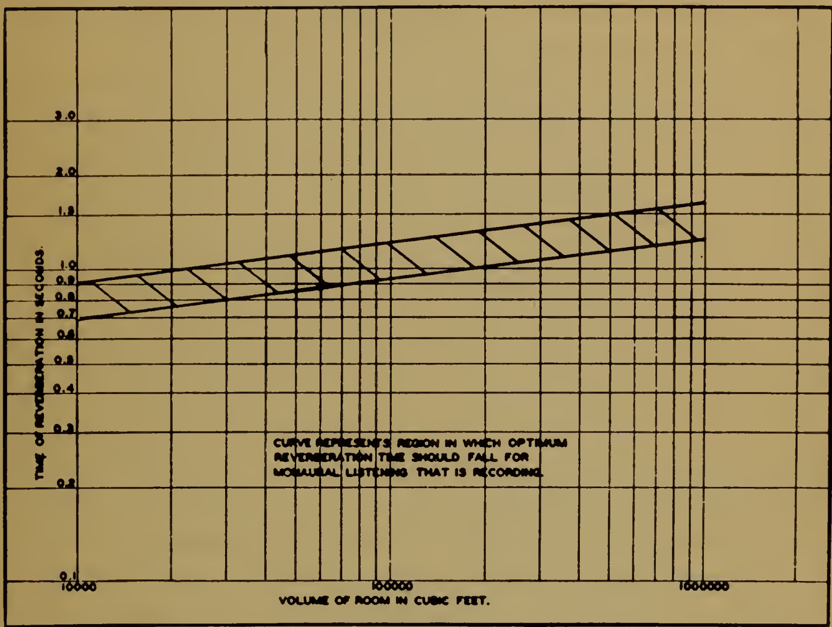

FIGURE 6

opposite one another, have very different voice intensities, it is legitimate to have one volume setting for the weaker voiced speaker and another for the louder voiced speaker. This technic should only be used when the speakers' voices differ sufficiently, so that they would be unsuitable from the standpoint of the legitimate stage. A second example would be the case of very soft dialogue of long duration occurring within a scene. It is then advisable to raise the level of this slightly, to avoid the danger of its being interfered with by surface noise after the prints become old. Other similar situations would naturally be handled in a similar manner. This rule might be restated as: Never touch the mixer dials during a take unless there is an important artistic reason for the resulting unnaturalness.

The final matter is scoring. Scoring is normally divided into two parts, pre-scoring and post-scoring. Pre-scoring refers to the condition where the sound record is made first, and the scene photographed synchronously with the playing of this record. The acoustics of pre-scoring should be designed to fit the acoustics that would be expected in the scene which is to be depicted with the sound record, and therefore each case is a problem of its own. However, the principles governing the acoustics for this type of scoring are similar to those for sets.

In general, pre-scoring is best limited to incidental music, music for dancing, marching or for other off stage sounds. It is difficult to pre-score a song in which the singer appears in a close-up or semi-close-up in the picture, since it has been found that the singer pays more attention to keeping in synchronism with the record than to acting. It is, therefore, preferable under these conditions to make a direct synchronous take.

Post-scoring is the addition of music and occasionally dialogue to a scene which has already been photographed. The greater part of post-scoring is done in a room or studio known as a scoring stage, the acoustics of which can be adapted to the requirements of this type of work. The two important acoustic factors controlling such a stage are first, its time of reverberation, and second, the distribution of sound absorbing, and sound reflecting material within it. It is well known that for two ear listening, the time of reverberation of a room for music depends upon the size of the room. This is also true for one ear listening or recording, with the difference that the numerical value of the time is less than for two ear listening.

The method of obtaining any given time of reverberation within a room is completely described in Watson's "Acoustics of Buildings." The time of reverberation which is most desirable for various sized rooms is shown in *Figure 6*. It should be noted that in this figure there are two lines plotted. The upper of these represents the maximum acceptable time, whereas the lower one represents the minimum time. Any value lying between these two lines is pleasing and leaves some leeway of choice to the musical director, as to just what he thinks is the best musical reproduction.

The distribution of the damping is shown approximately in *Figure 7*. It should be noted that this is an attempt to artificially reproduce natural listening conditions, namely, the music is reproduced in the live end, which would correspond to the stage of an auditorium, and the microphone is placed in the comparatively deader end, which would correspond to the audience position. The listening end of a room in an auditorium is not ordinarily

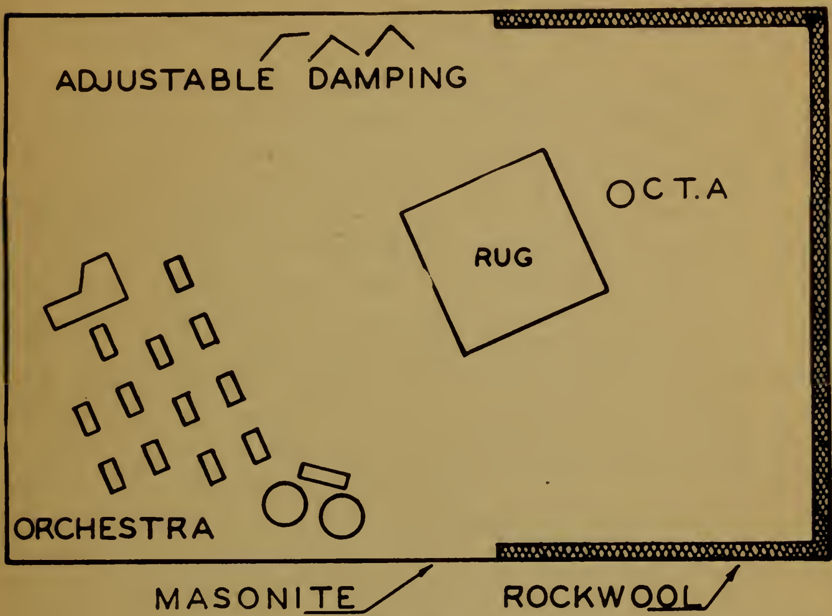

FIGURE 7

damped artificially, because the clothing of the audence constitutes very effective sound absorbing material.

The adjustable damping shown in *Figure 7,* is for two purposes: First to compensate for orchestras of different numbers of musicians, and second, to control the time of reverberation, so that it lies in the desired region as shown in *Figure 6.* Approximately 4 sq. ft. of rock wool 2″ thick is equivalent in damping, to the clothing of one musician.

There are probably many arrangements of the orchestra players, which will give highly satisfactory results. Considerable experience has failed to disclose an arrangement which is superior to the natural arrangement which the musical director would choose, were he giving a concert in a small auditorium. In view of the fact that it is often necessary to photograph an orchestra while playing, this natural arrangement, which is satisfactory from a visual standpoint, as well as a musical one seems desirable. It should also be noted that with such a natural arrangement, no special experience is required on the part of the musical director. Samples of orchestra recording, made with this type of arrangement, can be listened to by purchasing any of the symphony orchestra records made in this country by the Victor Talking Machine Company, and issued since the summer of 1927.

In scoring, as in ordinary dialogue recording, the dials should be operated as little as possible during a take. With orchestras of 30 pieces or less, it is scarcely ever necessary to touch the mixer dial during a take. However, with very large orchestras, a loudness range of 50 db is sometimes obtained, and this range is slightly too great to be handled with the present system. It is, therefore, necessary to do some manipulation. There are two ways in which this compressing of the range may be handled. The first is to permit the volume to rise fairly close to over-load and then begin cutting down on the volume control to avoid valve clash or the record cutting over. This method is probably the easier one for the untrained mixer, but unfortunately removes a great deal of the "punch" from the big crescendos. The second method requires some knowledge on the part of the mixer of the music that is to be played. When a crescendo is commencing, the mixer should start reducing the volume slowly before the loudness has approached the danger point, and having lowered it the requisite amount, leave it alone entirely for the remainder of the crescendo. In a similar manner the raising of the level for the very soft parts should also anticipate the actual pianissimo passage.

DUBBING SOUND PICTURES

By K. F. Morgan *

THE entire realm of trick photographing and duping as a necessary adjunct to editing of the silent motion picture now has its counterpart in sound production in the dubbing or re-recording process. Dubbing may be subdivided and classified as follows:

(1) "Scoring," or adding music to a picture that already has dialogue or sound effects.

(2) "Synchronizing," or adding new sound effects or dialogue in synchronism with a picture which has previously been photographed with sound.

(3) "Re-recording," or transferring one or more film or disc records to a new film or disc record by the electrical process originally used.

Thus the art of dubbing may be simply making a sound record with the microphone to match a picture, it may be the combination of new sound picked up by the microphone with one or more sound records already made, it may be the combining of sound records only, or it may be simply re-recording one sound record. The last mentioned has four principal purposes: First, to make a new master record; second, to transfer a record from film to disc or vice versa; third, to correct volume variations and other defects; and fourth, to provide one continuous uncut negative uniformly developed.

The dubbing process has been instrumental in supplying a unity and finesse as well as rhythm and continuity to the sound picture. There are some who believe that as the technique of sound recording is developed to a high degree, the need for dubbing will be diminished or even eliminated. However, dubbing has contributed largely to the success of recent sound pictures and the indications are that, in all probability, its application will expand with the development of the art.

Probably ninety per cent of all the world's present day machinery and electrical apparatus for adding sound to the silent drama has been installed and placed in operation in the last two years. While this tremendous demand for the manufacture and installation of equipment, together with certain contemporary modifications and developments found necessary in the field, was being met, it was natural that no great amount of thought was given to what might be considered a secondary adjunct, namely, re-recording or combining sounds for the final editing of a picture; consequently, this demand, almost as urgent as the first, presented itself when the first few pro-

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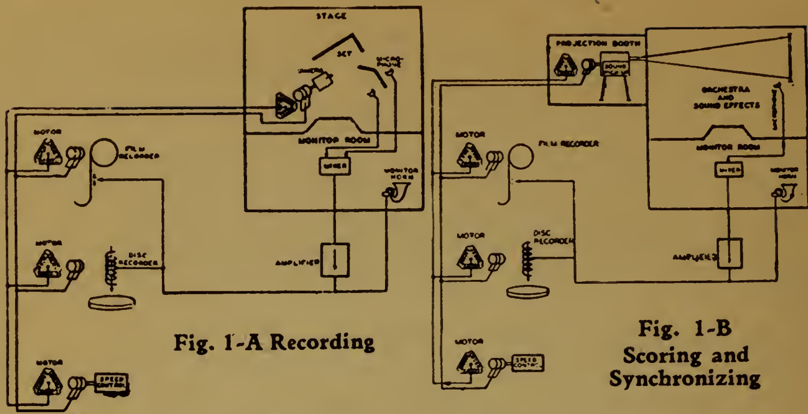


Fig. 1-A Recording

Fig. 1-B Scoring and Synchronizing

ductions were ready for editing, and while the recording installation work was at its height.

Plans were under consideration, it is true, providing facilities for these processes at an early date, but it is doubtful whether or not anyone anticipated the variety of problems that would present themselves in adapting sound production to all the "tricks" of the motion picture art.

The first synchronized talking pictures were short Vitaphone subjects and Movietone news reels. In either case, the cutting and editing was fairly simple, each take being one scene complete in itself. About the same time, due to the demand for "sound" pictures, there were those with electrical sound effects manually operated at each performance, not being mechanically synchronized with the picture. Then came the practice of making records of sound effects or dialogue to match the silent sequences. Schematic drawings indicating the general methods used in recording, scoring and synchronizing, are shown on Figure 1, A and B. A close similarity between these processes will be noted from an inspection of the figures. In synchronizing and scoring, a projector and screen replace the camera and stage.

The introduction of synchronized sound and dialogue into pictures of feature length presented the problem of sound cutting. When the sound was recorded on film the problem was fairly simple since the sound track could be cut in the same manner as the picture. With the original recording on disc, the cutting became a rather involved mechanical as well as electrical process since the scenes as recorded had no definite chronological relation to the final product. This introduced the first necessity for re-recording sound. The re-recording methed required the use of a number of disc reproducing machines so connected as to operate in synchronism with a recorder. The sequence and duration of the various takes on several original records having been determined, a cue sheet was prepared.

The application of the cue sheet involved a revolution count, which insured the cutting in and out portions of these sound records in the sequence of the cut picture. This process required operators at the turntables as well as personnel for counting revolutions and cueing. Subsequently, the counting was simplified by the use of a record which reproduced the revolution count. Finally a machine was developed which rendered the process automatic.

Early sound pictures, due to recording and production problems, were part talking, with the silent scenes scored, and sound effects added. The latter was accomplished by projecting the picture upon a screen on the recording stage where the desired sounds could be produced. If the projection and recording machines were interlocked by a synchronous motor system, the resultant sound record would be in synchronism with the picture. A schematic drawing indicating such a set-up is shown on Figure 1-B. Synchronizing and scoring are now extensively employed. The results are often more satisfactory when the original take involves dialogue only, than when all the incidental sound effects are recorded at that time. This is true for two reasons: First, many exterior shots must be built up on the sound stage and it is not possible to accurately simulate the actual condition of accompanying noise. This applies particularly to street scenes and scenes involving water or rain effects. Second, revolver shots, explosions, or other violent noises will often sound unnatural or have too severe an action on the recording medium to be included in the original take. In these cases the scene is taken minus the sound effects and these effects are synchronized after the picture is completed.

There were early ideas of accumulating "libraries" of recorded sound effects which could be introduced into a picture where needed. In order to add sounds (original or recorded) to those of a picture already produced, it is required that the original be re-recorded. A schematic drawing of a re-recording system is shown on Figure 3. This was the function demanded in the studios just as it seemed that the production of "all talking" pictures was safely under way. Several important pictures had been scheduled for release, and were nearing completion when it was found necessary to perform all of the above mentioned processes before release could be made.

As stated above, the need for dubbing was anticipated. In fact, it was considered as a simple application of already developed processes. This in a measure was correct, but even the combining of known processes presented detailed problems, which required a certain amount of engineering. When the sound currents are obtained from a disc or film record rather than from a microphone direct, the pickup must be made to reproduce the original sound currents with the utmost fidelity. Extraneous noises must not be introduced in this process of re-recording. These problems, together with a somewhat different circuit layout, constitute a part of dubbing which will be considered later in more detail.

Fig. 4 shows the various steps of recording and re-recording sound. These drawings indicate the rather unusual transformation which takes place during the interval from the picking up of the original sounds to their restoration in the theatre. Referring to the simplest of the processes, namely, recording and scoring on film, it is of con-

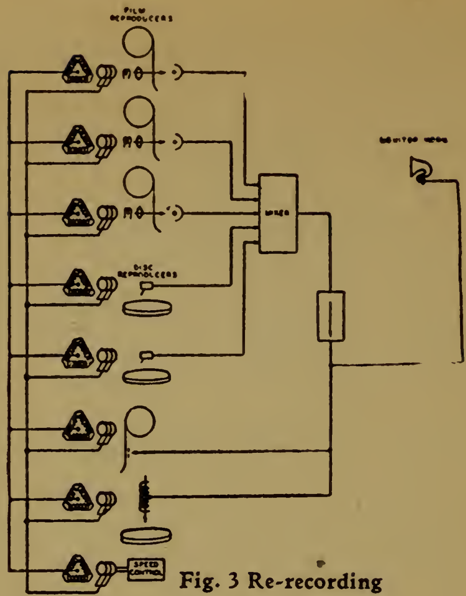


Fig. 3 Re-recording

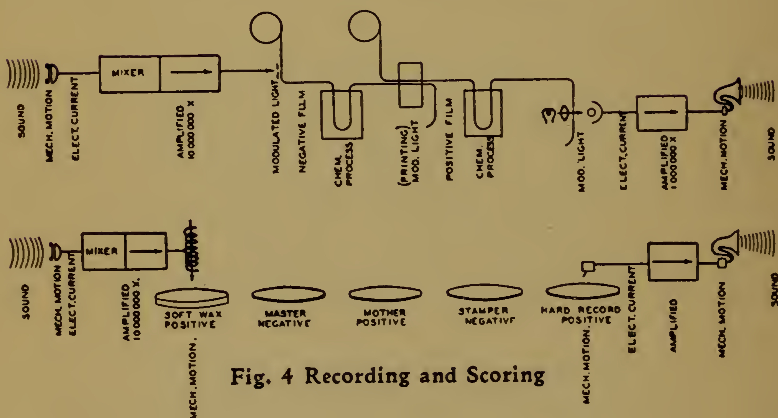


Fig. 4 Recording and Scoring

siderable interest to trace these changes. Beginning as sound waves, mechanical motion is imparted to the diaphragm of the condenser transmitter. This mechanical motion is in turn translated into a minute electric current. After being amplified the power of this current modulates a light to which film is exposed. The resultant latent image is treated chemically and when developed, again modulates a light to produce the positive. After development this positive, when run through a projector, modulates a beam of light, thereby controlling a minute electric current. After amplification the resultant power is sufficient to impart mechanical motion to a loud speaker diaphragm, thereby producing a very close approximation to the original sound. Beginning as sound, fourteen changes of condition must be passed through before the sound is re-formed. The same number of changes occur in recording on disc.

The changes in condition in the recording process are as follows:

Film		*Disc*	
0	Sound	0	Sound
1	Mech. Motion	1	Mech. Motion
2	Small Current	2	Small Current
3	Large Current	3	Large Current
4	Mod. Light	4	Mech. Motion
5	Latent Image	5	Soft Wax
6	Metallic Image	6	Master
7	Mod. Light	7	Mother
8	Latent Image	8	Stamper
9	Metallic Image	9	Hard Wax
10	Mod. Light	10	Mech. Motion
11	Small Current	11	Small Current
12	Large Current	12	Large Current
13	Mech. Motion	13	Mech. Motion
14	Sound	14	Sound

When sound is re-recorded there is no intermediate sound step, the energy representing the sound being dealt with in the electrical state. From the standpoint of the changes involved, synchronizing and re-recording are similar, as shown on Figures 5 and 6. These

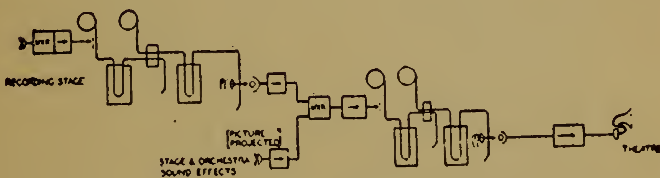


Fig. 5 Synchronizing

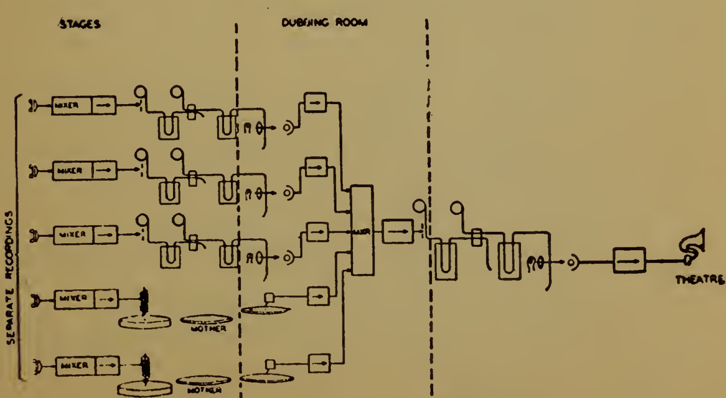


Fig. 6 Re-Recording

latter processes involve 25 changes of condition when re-recording from film to film and 22 changes of condition from disc to disc.

The changes in condition in the re-recording process are as follows:

Film		*Disc*	
0	Sound	0	Sound
1	Mech. Motion	1	Mech. Motion
2	Small Current	2	Small Current
3	Large Current	3	Large Current
4	Mod. Light	4	Mech. Motion
5	Latent Image	5	Soft Wax
6	Metallic Image	6	Mother
7	Mod. Light	7	Hard Wax
8	Latent Image	8	Small Current
9	Metallic Image	9	Large Current
10	Mod. Light	10	Mixing
11	Small Current	11	Large Current
12	Large Current	12	Mech. Motion
13	Mixing	13	Soft Wax
14	Large Current	14	Master
15	Mod. Light	15	Mother
16	Latent Image	16	Stamper
17	Metallic Image	17	Hard
18	Mod. Light	18	Mech. Motion
19	Latent Image	19	Small Current
20	Metallic Image	20	Large Current
21	Mod. Light	21	Mech. Motion
22	Small Current	22	Sound
23	Large Current		
24	Mech. Motion		
25	Sound		

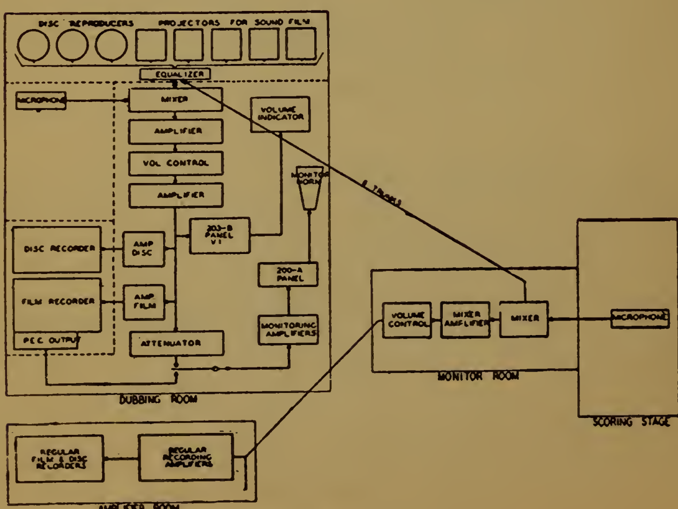


Fig. 7

It was found desirable to arrange the amplifiers in the reproducing circuit so as to reduce mechanical vibration to a minimum. Special amplifiers were built to meet the requirements of re-recording work.

It was also necessary to carefully guard against noise being introduced by circulating currents and foreign potentials.

The process of recording is such that there is a tendency for the high frequencies to the relatively under emphasized. This tendency is not objectionable in the original recording, but becomes undesirable in successive recordings, since it is cumulative. Fortunately, it is possible to do almost anything desired with the frequency response of the electrical portion of the system, hence it was only necessary to design an equalizer to counteract the over emphasis of the low frequencies. Due to the variation of different records, the equalizer was made adjustable.

Photographs illustrating dubbed sound tracks are given on Figure 8. The process of dubbing two separate records together is illustrated by track 4, which was produced by combining tracks 3 and 5. The original tracks, 3 and 5, are single frequencies. A re-recording composed of speech and music is illustrated in track 7, being the combination of tracks 6 and 8. From an analysis of track 7, its component parts could be shown to consist of tracks 6 and 8, although with such complex sounds it is not as apparent to the eye as the dubbed track composed of two different sine waves illustrated in track 4. Track number 1 has been combined from two separate records of music and dialogue. This record was then re-recorded four times, track number 2 in the picture being the fifth successive re-recording. It will be noticed that successive re-recordings tend to diminish resolution, which of course affects quality. When the fifth re-recording is projected and the sound compared with the original recording, the quality is not greatly impaired. Such an experiment as this requires the utmost care and supervision, but indicates the possibilities of re-recording. In general, although each re-recording actually introduces a slight loss in quality, in some cases defects in recording, such as "tubbiness" may be artificially improved.

The processes outlined are in a stage of development; consequently the space allotted to this equipment and the type of layouts in the various studios are by no means uniform. It may readily be appreciated that in scoring a picture, the standard recording channel can be used as the pickup by microphone, as in regular picture production, and the mixing is essentially the same. This also holds for the synchronizing operation such as adding sound effects to a completed picture. In the case of re-recording, it is desirable to adjust the volume of the output of the disc and film reproducers so that it may readily be mixed with musical accompaniment and sequences, and thence put through the regular channel. Due to the threefold function of dubbing, it is, of course, desirable to provide for utmost flexibility in the wiring scheme, as indicated to some extent in Figure 7. This, of course, applies to the signaling and motor system, as well as the transmission circuits.

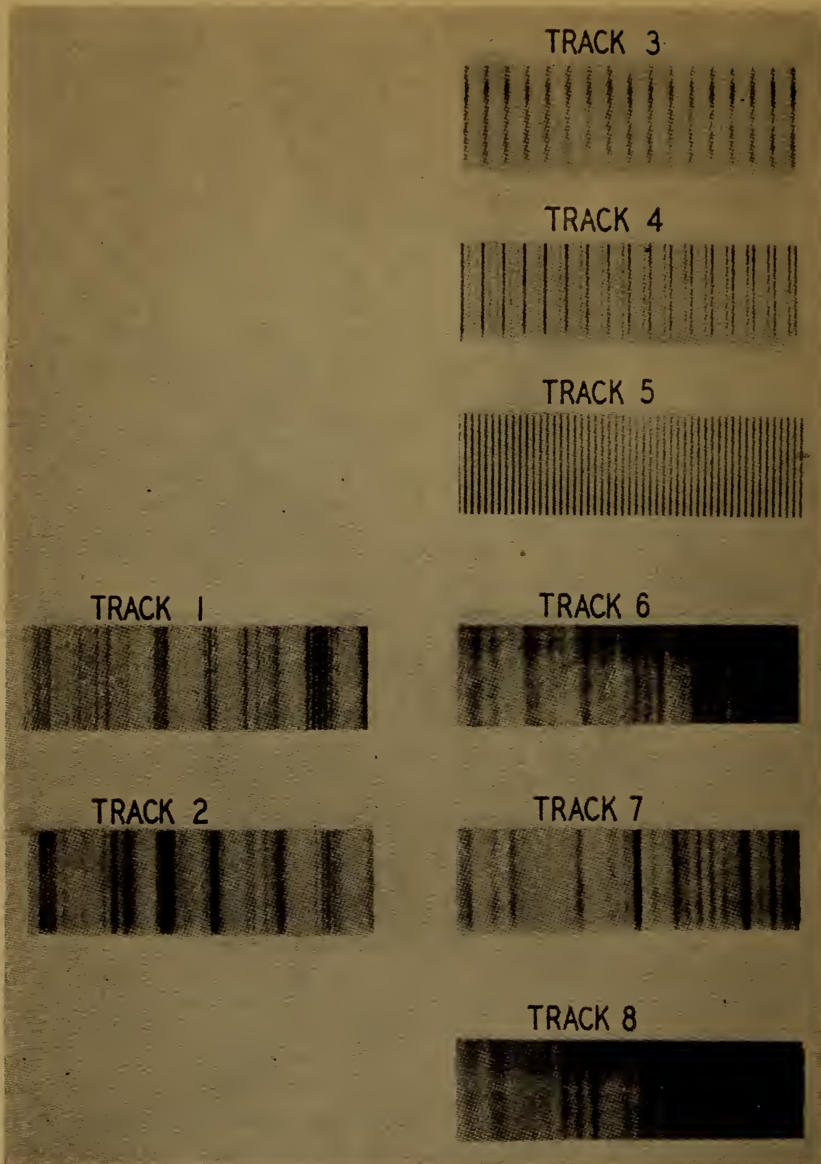


Fig. 8

RECORDING SOUND ON DISC

*Col. Nugent H. Slaughter**

The development of commercial talking pictures first assumed a practical form from the experiments which started at the Brooklyn Vitaphone Studios in 1925. At that time, the only method of recording suitable for this work was the disc method, long employed in phonograph recording. The availability of this thoroughly developed method of recording contributed largely to the rapid progress made in the new art. Naturally, in the application of disc recording to talking pictures, many new problems have been encountered; but all such problems have been solved as they have arisen.

The important features of any method of recording are quality of reproduction, uniform and reliable performance, and adaptability to a rapidly changing art. In all these respects disc recording compares well with other methods.

The recording of sound on disc involves processes entirely common to other systems of recording, except for the actual conversion of electrical energy into some form of permanent record and the steps immediately following up to the point where the record is employed to re-establish electrical energy. Since those processes common to other systems of recording have already been described in some detail, this discussion will be confined to the processes peculiar to wax recording and their analogy to certain processes in film recording.

The material used in the actual making of a disc record may be called the wax negative stock corresponding to the negative film employed in the film recording process. The wax negative consists of a soft wax blank in the form of a very thick disc which has a consistency and appearance much like beeswax. Its surface must first be prepared, not by sensitizing, as in the case of film, but by a smoothing process known as wax shaving, which makes the wax negative receptive to mechanical, rather than light, impressions. The shaving of wax is accomplished on

**Chief Engineer in Charge of Recording for Warner Bros. Vitaphone Productions*

machines such as are illustrated in *Fig. 1.* A closer view is shown in *Fig. 2* in which a wax may be seen rotating under the cutting knife, while a suction tube draws away the shavings so produced. This entire machine must be set up with great precision so that

FIGURE 1

Corner of a Wax Shaving Room

it will be free from vibration and so that the carriage which supports the knife and moves it across the wax will perform in a very uniform manner. Most important of all is the cutting knife itself which is ground from selected sapphire, the only material which has proven satisfactory for this exacting service. The grinding is done with the finest of diamond dust and is carried out with the greatest of skill and care to obtain a cutting edge more than a half inch long which will be so perfect that it will leave the wax with a mirror-like finish. In the illustration *(Fig. 2)* the difference between the smooth outer portion of the wax, which has already been finished, and the rougher central portion is discernible.

Occasionally one of these spinning waxes will break because of some internal defect, and fly off the turntable of the wax

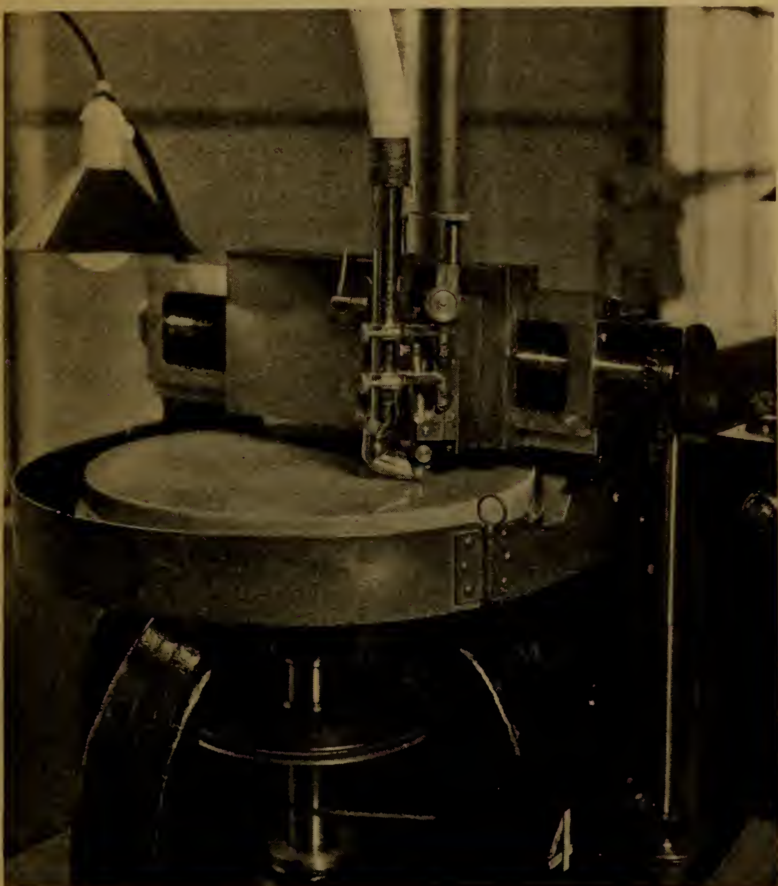


FIGURE 2

Wax Shaving Machine in Operation

shaving machine with serious results for the operator. For this reason the hinged guard, which may be seen in the illustration, has been provided.

In spite of the great precision required in wax shaving, the cost of wax "negative stock" is very much less than the corresponding cost of film negative stock, the saving amounting to many thousands of dollars annually for a studio of moderate size.

In the recording of a disc record one of these wax negatives is placed on the turntable of a disc recording machine, as may be seen in *Fig. 3.* This turntable is driven through a system of gears

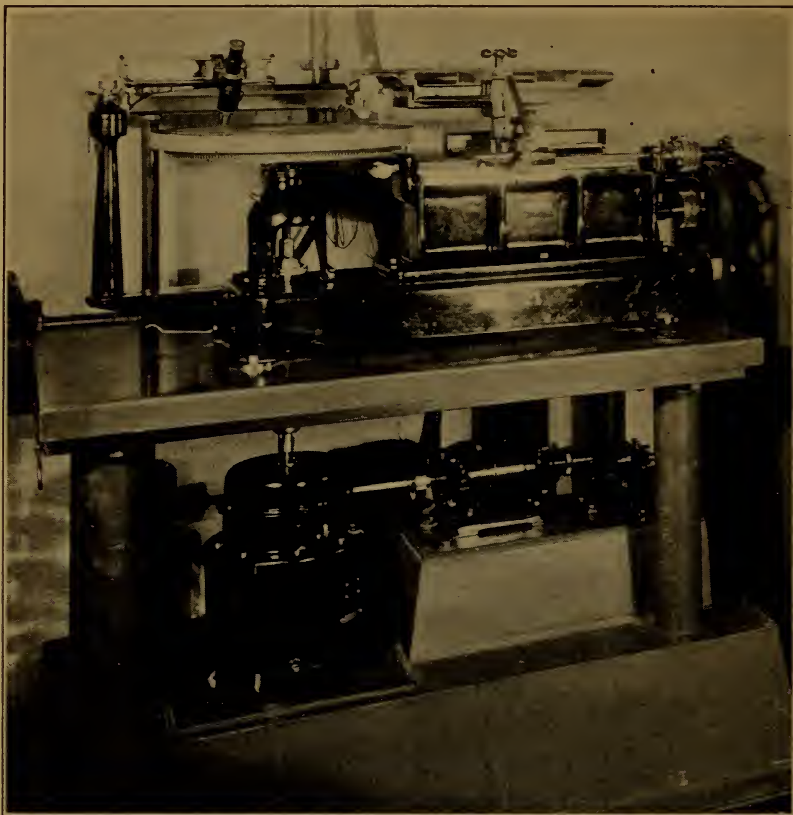


FIGURE 3
Wax Recording Machine, Showing Drive Mechanism

enclosed in the large gear pot shown directly beneath the turntable by means of a motor which is at all times synchronous with the motor used on the stage to drive the camera so that the proper relative speeds of the wax and film required for synchronism will be maintained. The record speed is 33 1/3 r.p.m. which corresponds to 90 feet per minute traveled by the film in the photography or projection of sound pictures. The large gear pot contains an oil damping arrangement designed to eliminate any small speed variations of the turntable which might other-

FIGURE 4

Wax Recorder in Operation

wise be introduced by the motor and gears so that the speech or music recorded will be entirely free from flutter.

An electrical recorder rests lightly on the surface of the soft wax, as seen at the right in *Fig. 4,* and by means of a sapphire cutting jewel or stylus cuts a shallow groove in the wax as it rotates. The depth of this groove is controlled by a sapphire advance ball which may be adjusted by the thumb screw at the right of the recorder. As the record rotates the recorder as a whole is slowly drawn from the inner part of the record toward the outer edge so that the groove has the familiar spiral form.

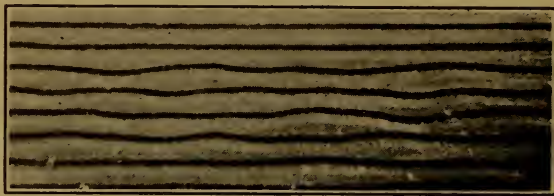


FIGURE 5

Enlarged View of a Wax Record

The rate of advance of this spiral may be set at any one of three different speeds by means of the gears seen at the upper right of *Fig. 3.* The speed chosen will depend upon the character, particularly the loudness of the sound being recorded. At the beginning of each record a much wider-spaced spiral is used to separate the start of the first groove from the body of the recording so that the operator in the theatre will have no difficulty in setting the needle of the reproducer exactly on the starting point. This special spiral groove, which lasts for about one turn of the record, is accomplished by a cam which engages for this first turn only.

As the record proceeds the speech or music sounds on the stage set up an electric current in the system which is essentially an electrical copy of the sound, and this current is applied to the electrical recorder, causing the stylus to move from side to side so that the groove which is cut in the wax will have the characteristic wavy appearance shown in *Fig. 5.* The means of accomplishing this side to side motion is illustrated by the diagramatic view of the recorder in *Fig. 6.* A strong magnetic field is set up across the pole pieces by means of the magnetic field coil. The diamond shaped armature to which is rigidly connected the cutting stylus stands in this magnetic field between the pole pieces, and around it are placed the two speech coils through which are passed the amplified electric currents from the stage. These currents cause either end of the armature to be poled alternately north and south magnetically in accordance with the speech current, and the resulting magnetic forces cause the armature to rotate or oscillate about its axis, thus moving the stylus from side to side.

At the conclusion of a scene or take we have in the wavy grooves, which are illustrated in *Fig. 5,* something which corre-

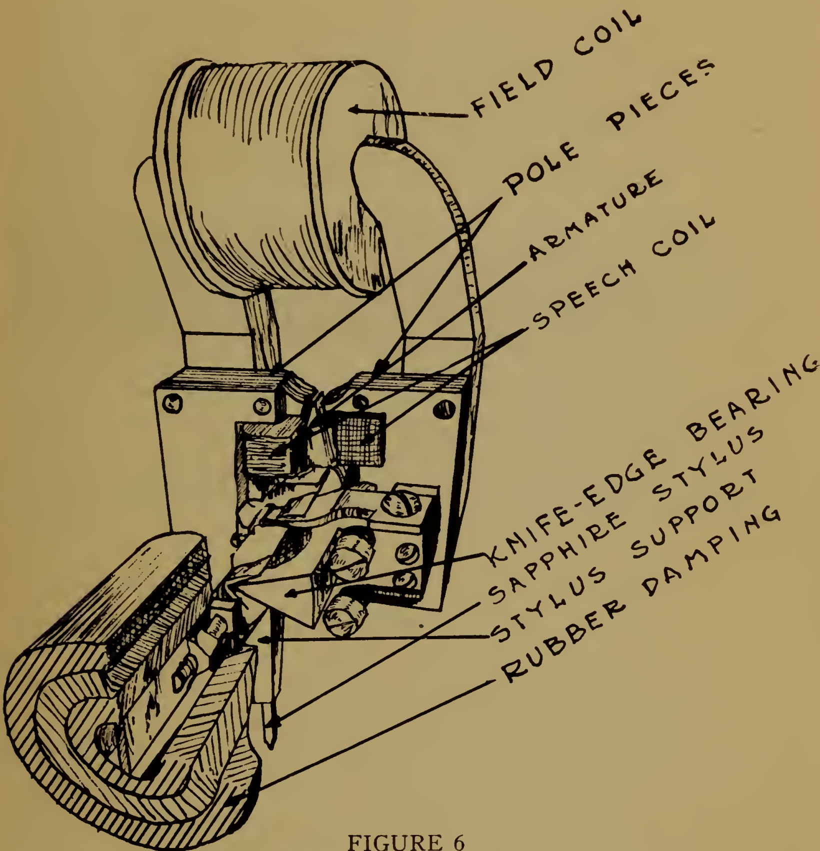


FIGURE 6

Sectional View of an Electrical Recorder

sponds to the latent image on a piece of film which has been exposed in the film recording machine. There is, however, one important difference in the fact that the wax record may be immediately used, if we so desire, to reproduce the sounds which were recorded on it. This procedure, known as making a playback, usually results in sufficient damage to the wax so that it would be unsuited for use as a final reproduction. For this reason an extra wax is usually recorded where a playback is required. These playbacks from soft wax records are frequently of great value, not primarily as a check on the recording but rather as a check on the performance which has been recorded. Many directors rely to a large extent on playbacks, while others take little interest in them. Although their true value in aiding production cannot be accurately estimated at present, playbacks will certainly find a place of much importance in the ultimate scheme.

FIGURE 7

Magnified Cross-Section of Grooves in a Wax Record

Having completed the recording of a scene which the director has approved after hearing one wax played back, the other wax record or records go through additional processes which correspond generally with the film development and printing. After suitable preparation, the wax record is immersed in an electroplating bath by means of which a heavy layer of copper is deposited on the surface of the soft wax. This copper layer or shell, when separated from the wax, constitutes an exact copy of the original recording, except that it is negative in character, bearing ridges where the original record bore grooves. This difference is illustrated in *Fig. 7,* where the black portion represents a cross-section of an original wax and hence the white portion may be taken to represent the copper shell which has been obtained from the original.

This shell is called a matrix, or sometimes a master negative, and is used to make a few of the familiar black pressings or finished records. In the case of original recordings these records may be used for re-recording, whether preliminary or final, and in the case of final recording they are used in testing the quality of the recording and of the production. For studio uses, therefore, the additional processes corresponding to the printing and developing of a positive film are not necessary, a fact which results in further savings of many thousands of dollars annually.

For theatre use, however, where thousands of finished records are required, the risk of damaging the original matrix is sufficiently great to justify two additional steps in the process. The matrix is electro-plated to derive one or more metal records,

FIGURE 8

Record Press, showing finished record just removed from the dies, and record stock heating on the steam table.

sometimes known as mother records, which are in all respects similar to a finished record except that they are composed of metal instead of the familiar black compound. These metal records then become the new source from which are derived by electro-plating as many metal negatives, known as stampers, as may be required for use in producing the finished records. Fortunately, these electro-plating processes, unlike the corresponding sound film processes, have been highly developed by years of experience and may be performed with negligible loss of quality.

The making of records of the "dailies" for studio use involves the use of the original copper matrix as a "stamper." This matrix is placed in a steel die in the record press, shown in the accompanying illustration, *Fig. 8*. Record stock is heated on an adjacent steam table until it becomes quite soft. This stock is then rolled into a plastic ball and placed on the stamper or matrix, which is heated by steam in the dies to much the same temperature as the steam table. The press is then closed, and by means of a hydraulic pressure of more than a ton per square inch the record material is pressed into the minute sound grooves of the matrix. Cold water is then turned into the dies, and after a short inter-

FIGURE 9
Electro-Magnetic Reproducer

val the press is opened and the record is separated from the matrix. It is then ready for use.

The same operation is repeated as many times as required to provide the desired number of copies. Both in cost and time required the making of these records is very small compared with sound-on-film records.

In order to re-create sound from a finished record in the theatre, some form of reproducer must be provided which can first convert the wavy groove on the record into electric currents which will be essentially the same in form as those set up by the microphone on the stage. For this purpose a device similar to a recorder, but equipped with a needle instead of a cutting stylus, would serve. The type of reproducer ordinarily used in the theatre is illustrated in *Fig. 9,* and though different in physical form, it is the same in principle. The most important difference lies in the provision of a permanent magnet to produce the flux across the armature instead of the electro-magnetic field coil used in the recorder. This results in a very desirable simplification of the theatre equipment.

The degree of faithfulness with which the current set up by the reproducer will simulate the recorded current will depend principally upon the electrical characteristics of the recorder and the reproducer. *Fig. 10* indicates that the recorder operates with

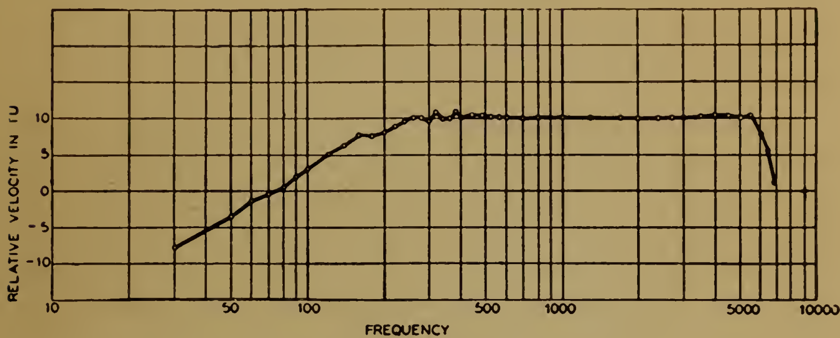


FIGURE 10

Frequency Characteristic of an Electrical Recorder

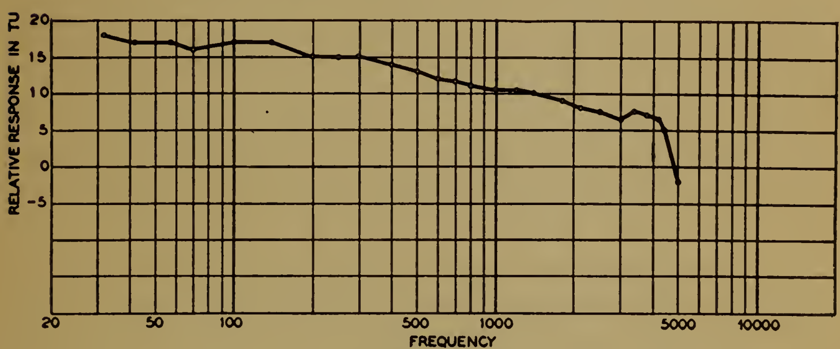


FIGURE 11

Frequency Characteristic of a Typical Reproducer

uniform efficiency over a band of frequencies extending upward to 5,000 cycles, which is about the upper cut-off frequency used in the theatre. At the low frequency end the recorder efficiency droops in a manner which helps to avoid over-cutting of the wax and at the same time partially compensates for the tendency of the stage and theatre acoustics to over-emphasize the very low frequencies. The reason for a consideration of over-cutting of the lower frequencies is not apparent from the curve of *Fig. 10,* unless it is remembered that the recorder is a constant velocity device and that the curve is plotted in terms of relative velocity. This means that for a given input voltage to the speech coils of the recorder, the amplitude of the wave on the wax at a frequency of 200 cycles will be twice as much as the amplitude for 400 cycles, and five times as much as the amplitude for 1,000 cycles, etc. Since it also happens that the energy of speech lies principally in the lower frequencies, it is obvious that the heaviest waves on the wax and therefore the greatest tendency for two adjacent grooves to cut into each other, occurs at the lower frequencies.

Some idea of the precision with which this stylus of the recorder must operate may be gained from a consideration of this frequency characteristic and some of the dimensions involved. Since a pitch of 92 is normally employed, the center to center spacing of the grooves on a wax record is about .011 inch. The width of the groove itself is about .006 inch, so that about .005 inch is available for lateral motion of the stylus—half of this amount to either side of the mean position. Since the maximum amplitudes occur at the lower frequencies because of the constant velocity characteristic of the recorder (above 200 cycles) the amplitudes of the higher frequencies will be exceedingly small. Assuming a full cut wax having roughly equal levels of a variety of frequencies present the 200 cycle amplitude will be about .002 inch to either side of the mean. The 1,000 cycle amplitude will be about .0004 inch, 2,000 cycles .0002, and 4,000 cycles about .0001 inch. Assume then that the volume drops about 20 db—a not uncommon range in talking picture work—and the amplitude of the 4,000 cycle wave becomes .00001 inch, or about ten millionths of an inch. It is because of these small amplitudes that the microscope seen at the left of *Fig. 4* becomes a useful accessory to a wax recording machine, affording a ready means of determining the character and general level of the record.

The overall characteristic of wax recording must take account also of the electrical characteristics of the reproducer. The curve of an average reproducer is shown in *Fig. 11.* When combined with the characteristics of the recorder, shown in *Fig. 10,* a gradual droop toward the high frequency end results. An additional, but smaller, downward trend toward the high frequency end results from a mechanical effect which is analogous to film transfer loss. This effect results from the relation between the finite size of the needle point, which must be used in practice, and the length of the waves in the groove representing the higher frequencies, as a result of which the needle tends to bridge over the high frequency modulations on the wax just as the finite width of the slit used in the film reproducing equipment tends to integrate over the higher frequencies with consequent loss of volume.

The combination of the recorder and reproducer characteristics with this latter effect represents only that portion of the overall frequency characteristic of sound pictures which is contributed by the actual recording and reproducing processes. It does not include such important effects as the acoustics of the stage, the characteristics of the microphone, the amplifiers and the horns and the acoustics of the theatre. Any attempt to compensate for the recording characteristic alone would be worthless. On the other hand, the characteristics of the recording system as a whole may be readily adjusted to produce the most pleasing final result in the theatre.

To the low cost of wax negative stock and the needed "prints" or finished records for studio work may be added the important advantage of simplicity of handling. Playing the records in the studio involves devices which almost everyone understands sufficiently to operate intelligently, and which can be readily duplicated throughout the studio to whatever extent is desired. For many purposes a phonograph, modified only as to turntable speed, is sufficient.

In actual recording on the wax disc, practically everything that might affect quality is disclosed during the recording period or immediately afterward by visual inspection of the wax. This is well demonstrated by the fact that much less than one per cent of the records which are processed prove unsatisfactory from a recording standpoint.

The disc recording machine has usually been regarded as a stay-at-home machine, resting comfortably on a vibrationless foundation with carefully controlled temperature, dust free air and other highly special conditions. This is certainly the opposite to a desert location set-up with temperatures well above a hundred degrees, and a truck body as the home of the machine. Many records have been made on location under such conditions, with results not distinguishable from studio records. This is a good example of adaptability of disc recording to special conditions.

The cutting of talking pictures represents the most difficult problem encountered in the use of disc records. Special equipment has been provided for cutters, and the use of this equipment has enabled the cutters to work in a very satisfactory manner. Composite records are made of each reel at various stages of the cutting, which makes the picture and records suitable for any projection room.

In these so-called pre-dupe records opportunity is afforded to approximate the final product in such matters as adding sound effects, and modifying the loudness, thereby giving a better basis for criticism than if the original records were used without any such desired changes.

After the cutting of a picture has been completed, the records corresponding to each reel are re-recorded from the individual "dailies" of original dialogue, songs or other material. This process involves extremely accurate timing of each individual record so that it corresponds with the action of the picture film. It involves the correction of any unwanted variations in loudness of different records, and also occasional intended variation of loudness to correspond with the picture. Sound effects of appropriate nature are added, together with music, for certain scenes. At times the sound on the final record will be a composite of three or more individual records, all properly timed and balanced for relative loudness. The timing is all controlled automatically from predetermined cues.

In production work, speed is all-important. At times, delays of even a few seconds seem important, hence it is necessary that recording operations involve nothing that will hold up shooting. Experience shows that recording on disc machines meets this requirement in an entirely satisfactory manner.

It is true that disc recording calls for the use of things which have not heretofore invaded motion picture studios, but a wax shaving machine or a record press should not be nearly so offensive as a microphone. The former devices are behind the scenes, working so effectively that their presence is never suspected, while the microphone is still regarded with a certain degree of suspicion.

As illustrating the efficiency with which the wax negative is developed and printed, records are made available on an overnight basis in any quantity which the various studio needs require. In emergencies the records can be processed in three hours after being recorded. Additional records can be obtained on a few minutes' notice if required in a hurry. In this respect, the disc record keeps pace with the ordinary schedule of development of the picture film.

Good quality of reproduction is essential, and this quality must be consistently obtained for successful work. Disc records can be duplicated without limit as to number, and each record will be just the same as all others.

The disc record has, to a high degree, the very essential element of consistency; that is, the quality of recordings from day to day is not affected appreciably by the recording medium. The quality of reproduction can be intentionally varied over a wide range by electrical circuit changes, and thereby many defects arising from inefficient pick-up of sounds can be partly eliminated. While this is true of any method of recording, the consistent quality of disc recording makes easy such corrections.

Surface noise is usually determined by undesired sounds on the recording stages, chiefly camera noise. Where only the wanted sounds are recorded, the surface noise is largely negligible.

From the viewpoint of production efficiency, the disc record has the merit of being ready to go at all times on a moment's notice with breakdowns or failures very rare. It has become well adapted to studio use, and imposes no restrictions on the cast, the director or the cutter that are not fundamental to the art of recording. Its present efficiency is only another example of adapting a well established art to a new field of endeavor.

The talking picture art is new, and so is the technique of recording as applied to picture work. As the art progresses, it may be expected that disc recording will make further contributions to its progress.

NON-THEATRICAL MOTION PICTURES

Milton Stark

THE Non-Theatrical Motion Picture, as the name implies, refers to the art of the Motion Picture applied outside the theatre. However, Motion Pictures have been made for Non-Theatrical purposes that have been accorded honor places on the Theatrical screen. For instance, the pictures "Chang" and "Simba," which graphically picture animal life, were originally meant for scientific visual records. They were so interesting and so well taken that it was decided to lengthen them. And, with the addition of some scenes of the natives in a love theme, the films were successful commercially.

Making Non-Theatrical Motion Pictures is a fascinating business. Just picture yourself, for instance, assigned to "shoot" or record with your camera a few scenes like these: A railroad car loaded with grain, that is actually turned upside down so that the grain will be emptied much faster than the old way of shoveling. An entire trip through a packing plant, where the story of meats is visualized—from the cattle starting up the incline, to the finished products being taken away in refrigerated cars. A hunting trip where everyone else had their guns and you had to "shoot" with your camera.

The very first Motion Pictures ever made were made for Non-Theatrical purposes. In 1872, Edward Muybridge perfected a device that took pictures of running horses. It consisted of a series of cameras to which were attached strings that ran over the running field. As the horses passed them the strings broke and tripped the camera shutters. The pictures, when developed, actually showed the running horses—and were used to settle all doubt as to the real winner. Muybridge continued his experiments at the University of Pennsylvania, with a sum of money donated specifically for his experiments "in the cause of education and science." That was long before the talkies, grandeur, third-dimension and color-film were thought of as commercial successes.

Non-Theatrical Motion Pictures can be classified, rather broadly, into three groups, the Industrial, the Educational and the Scientific. The film on the packing plant is an excellent example of a typical Industrial. It was made to be used in the sales and advertising departments of a large Eastern packing-house. The funds were appropriated and the amount carried in the budget as a definite part of that firm's advertising allowance. It was really an investment in that it has already brought in enough new business to pay for three or four films (negative and all)—and is still in constant circulation.

It is interesting to note that, while we know the Motion Picture business as an art, comparable with the drama, etc., motion pictures as an industry in the beginning were principally film productions with industrial or advertising themes. It was quite a time, from the actual perfection of commercial Motion Picture projection, before the industry started into theatricals. And even then the very first half-reel and single reel subjects cleverly, though not neatly, used advertising inserts to help pay for the film. You don't have to be an old timer to remember when, as a form of advertising, the older companies used a panel, or sign, in every set with the name of the company in heavy letters. That was advertising that seemed to be effective, because later when the first purely advertising films were made, the boss or advertising man, or sales manager were sold much quicker on having a film made, when a close-up of them was inserted. Even though their pictures didn't help the film a bit.

Gradually, when Movie audiences grew larger and re-converted stores were torn down to make room for specially built "Movie Parlors," business men started to take these films seriously. They saw crowds of people eagerly spending nickels to sit in stuffy rooms and listen to bad music and watch poor pictures. The business man with foresight pictured this enormous group of people looking at a screen, and wondered why they couldn't be looking at his product, or his services. No sooner said than done, and within a few years, every program had its advertising film as a filler. One of the very first organizations to cash in on this was the Ford Motor Company. They had their own Cameramen and made their own films. These films were exceptionally well done and pictured interestingly, all types of business such as a Modern Bakery—a Typical Furniture Factory—a Model Dairy—a Steel Mill—the story of rope, etc. The idea was so novel when they first appeared that most of the theatre managers ran them on their regular programs, not realizing that they were giving the automobile man invaluable advertising. Incidentally, even today, if you'll look—and listen—you'll see and hear advertising inserts paid for by national advertisers.

As Motion Pictures progressed, the advertising film developed. Organizations were established throughout the country that specialized in Industrial films. And before long the market was glutted with advertising films of one type or another. Some were good—but most were bad. In the meantime, film companies started making "Civic" films in small towns. These films were built on a "Civic Pride" scale and incorporated "shots" of the representative businesses and business men in the town at so much per "shot." They were made in novel forms such as taking the back of the heads of the leading babbitts and showing their faces the next week. All right for their purpose but eventually the well known unreliable and crooked type of promoter entered into the business and the whole idea was gradually discontinued after several of these "fly-by-nights" were handled by John Law. This type of producer is fortunately gone—but not forgotten. Only the other week one of our men approached a rather well known firm for a film, and was curtly refused an interview because, as we found out later, he had been swindled years ago by a man of the above type. It will be quite a while before this man can be sold, and I'm only citing this to point out what the average honest industrial producer has to contend with. The Industrial Motion Picture man of today, of necessity, has to be a reputable member of the city in which he resides. Business ethics demand it.

At present there are between 50 and 75 recognized organizations specializing in the production of "Industrials." And by "Industrials" we can include, rather roughly, films of these types: *Factory Films*—showing manufacturing processes; *Sales Films*—visualizing selling points of commodities, or services, as shown to prospective customers; *Medical Films*—made for individuals as well as Medical Colleges, etc.; *Progress Reports*—Motion Picture records of important happenings in civic affairs; *Social Films*—films that are made up for private purposes, or for annual dinners, etc.

So you see, an Industrial Film organization today has to be equipped to take all kinds of Motion Pictures under every conceivable condition, and while the theatrical man has to please his director only, quite often in this business we have to satisfy a committee of fifteen or more. The very life of our business depends on selling the "Ideas." Talk to the average man even slightly interested in movies, and he will invariably say: "Why don't you sell So-and-So a movie, they can use one." Easy enough to say so—but the industrial firms that are alive and kicking today are the ones who have been able to sell their "Ideas." That's all there is to it.

You can start an industrial firm yourself. No coupons to be detached—no books to read—no courses to take. All you have to have are a few Bell & Howell's, a complete laboratory, a few Cameramen (who have been making movies long before 16 mm. became popular)—a nice suite of offices, exceptional salesmen, strong financial backing—*brains, knowledge* (acquired through experience only), and pep, personality and *perseverance.* Get all this—build yourself a reputation in your community—and just as soon as you start to make money after *years* and *years* of missionary work, *sound enters* —and you've got to start all over again.

However, sound, if anything, will help the industrial film business. It will take just a bit for the necessary readjustment, but before long sound film (for industrial and educational purposes only) will be made for far less than the approximate $5 per foot price now—and portable projection units will cost much less, be more perfect, and be easier to handle than they are at present. In the meantime, the production of industrial silents is going on just the same. There are a few sound industrials in circulation today. The number is gradually increasing and every industrial firm has already made necessary contacts for sound films. This, notwithstanding the fact that recently all the major companies definitely established industrial departments. I'm not old. I've only been in this business about ten years, but in that time I've seen them come and go—and the only ones who always remain are the old established ones who don't try to grab too much, but are satisfied to gradually build their business by efficiently contacting and persistently working all available potential clients within an approximate area of several hundred miles from their laboratory. The firm, with headquarters in one city, cannot consistently and successfully compete with organizations 1000 miles away who have the necessary personal contacts that are vital in any worthwhile Industrial firm.

Educational Motion Pictures include about fifty per cent. of all

Non-Theatrical films. Movies are used to educate salesmen, employees in large plants, prospects in foreign countries, and theatrical audiences, as much as they are used in schools and colleges. Thomas Edison has said that Visual Education will eventually replace the textbook, for the pupil. But even though it is a scientific fact that 87% of all human knowledge comes through the eye, I feel that Visual education is only useful as a supplementary project. The eye is the most observant as well as the most retentive of all sense organs. If you don't believe it, try closing your eyes for about five minutes or so and think of all the things you know of in this world. The chances are that you will be able to trace most of your knowledge through your sense of sight. You've often heard the saying "In one ear and out the other" but never "in one eye and out the other," because sound travels at about 1100 feet per second while light travels approximately 186,000 miles per second, almost a million times as fast. Even the newsreels are educational films. Every large producer has a special newsreel department, entirely separate from the theatrical end.

During the World War, Motion Pictures as educational mediums for the instruction of the fighting man as well as the civilian, played an important part. Motion Pictures, for instance, were made in animated and straight photography showing the workings of the famous Liberty motor, and then shown to the men who would live through the arduous days ahead. The film, "Elements of an Automobile," which most graphically shows the functioning of every part of an automobile, is still being used today in trade schools and for technical groups.

Visual education is even invading the correspondence schools of the country. The student is enabled to literally *see* the story of electricity or radio or any other mechanical subject he is studying. And the examination questions are scientifically formulated on the typical visual reaction of the pupil. Enrollment in this type of school entitles the pupil to a 16 mm. portable Motion Picture projector and the use of 24 or more reels, instead of books. The Old Chinese proverb "One Picture is Worth a Thousand Words" is replaced with the American one "I'm from Missouri, show me."

A two-reel Motion Picture is available on the Einstein Theory of Relativity. While it would be unfair to say that everyone can understand the entire theory once he has seen the film, I do say that after seeing it he will, at least, be started on the right way of analyzing the theory. It will act as an inspiration to know more and will lead you the right way. Could you say the same of a book on the same subject?

Non-Theatrical Motion Pictures have even been made that visualize for the optience just why Movies are Visual aids. And in the scientific field, films have been made that show the heart beat of a human and the way the tongue moves in pronouncing every vowel and consonant. Microscopic Motion Pictures of a drop of water as the main actor, or a close-up of a fly's eye, or a spider weaving its web, and even the unusual spectacle of the metamorphosis of the butterfly are now so ordinary that they can be brought very cheaply for your little home movie projector.

Recently we made a Motion Picture of a major medical operation. The film, which illustrates a special technique, is now being shown to medical students. Unlike the theatrical film, we could not rehearse the scenes and had to take the action exactly as it occurred. In taking a microscopic film, for instance, the cameraman who acted as his own director, cannot tell Miss Microbe to smile a little broader, or turn her face to the light. If the film does not turn out he must make another and keep on shooting until he gets the desired results.

Readers of the sports sections of the daily newspapers are no doubt familiar with the fact that the athletic coaches of the larger colleges have their own Motion Picture equipment, including slow-motion cameras, with which they shoot movies of every important game during the season to be shown to the teams later for slow-motion analysis. One of the buildings at the University of Nebraska is a regular Motion Picture studio.

As early as 1900, Professor Carvallo of France succeeded in producing Motion Pictures showing the process of digestion in the stomach of a frog. This was followed by ultra-microscopic films made by Pathe, with the magnifications over 50,000 times natural size.

Motion Pictures have been made showing bullets leaving a gun and a recent experiment by the Bureau of Mines recorded a stick of dynamite as it exploded. Motion Pictures can photograph everything the eyes can see and many things the eyes cannot see. Thanks to the Non-Theatrical field, Motion Pictures are enabling us to picture for you the things we've always read about, but have never seen.

Motion Pictures can be applied to overcome space as well as time. It's purely a mechanical function of the camera and the cameraman to speed up or slow down and show flower buds opening into full-grown flowers. The film shows it in 15 minutes while the natural action takes 15 days.

The Industrial and Educational fields have been scarcely scratched. and ahead lie developments and accomplishments which today may seem unbelievable, providing every Industrial or Educational picture firm will be as diligent and progressive as have been the amusement film concerns. Ten years from today, I can visualize talking pictures carrying the sales campaigns of the big business houses into millions of homes where, instead of reading advertisements in magazines, housewives will simply slip a film into the home projector and listen to the explanation as she sees the picture of a new labor-saving device on the home screen. The possibilities in this field are almost beyond realization.

CINEMATOGRAPHY SIMPLIFIED

William Stull, A.S.C.

A FEW years ago, motion picture photography was, as far as the average photographer was concerned, a closed book. True, there were a few semi-professional cinematographers in the larger cities, and a handful of hardy cine-amateurs, but to the mass of photographers, (professional and amateur alike), cinematography was like some sort of Super-Eleusinian Mystery, to which only a very few of the elect might become initiates. The few venturesome cine-amateurs, as initiates to the mystery, were regarded with reverential awe; the professional cinematographers were treated as hierophants of a mystic temple; and the studio cinematographers—well, they could surely be nothing but lesser deities!

Of late, however, this has changed. Due to the practical idealism of one man, George Eastman, who thirty years ago made still photography practical for everybody, cinematography has become popularized. A new film system, inexpensive, and practical for amateur use has been evolved, and for it the makers of cinemachinery have created a variety of outfits which have leaped into universal favor almost over night. Small, durable, and amazingly simple, these outfits have brought cinematography within the reach of millions of photographic amateurs of all classes, from the most advanced to the "Brownie"-wielding tyro. And a remarkable percentage of the film that these millions turn out is at least passably good, for their cameras have been so perfected that they almost think for themselves. But no machine has yet been made that will not do better work if a little thought is given to its operation, and nowhere is this truer than in the case of cinemachinery. Even in its simplest state, the cinema camera is a highly specialized scientific machine. As such, it requires careful, intelligent operation to secure the best results; and before such operation can be given, the operator must have some understanding of the basic principles upon which it operates, and of the technique of its operation.

Cinematography means the making of moving pictures. But when we examine a strip of motion picture film we can at once see that there is no actual motion, for the film consists of a series of tiny still pictures upon a strip of celluloid: the motion is only evident when they are projected upon a screen by means of the proper machine. Essentially, then, cinematography consists of making a series of progressively differing still photographs of an object, which, when viewed in rapid sequence, give the illusion of exactly reproducing the original movement of that object. The apparent movement of the picture is due to a number of inherent nervous and optical defects which cause our mental image of each individual picture to remain for a fraction of a second after the picture itself has left the screen, and then to merge into the following one, giving the effect of a single, *moving* picture. This phenomenon is scientifically known as *Persistence of Vision,* and has been known to scholars from the earliest times, though until the comparatively recent invention of photography there has been no way of using it practically. However, since the coming of photography, the development of the moving picture has been merely a question of mechanical design.

Obviously, then, cinematography is a development of still photography, and rests on the same foundation. Photography in turn is essentially the manipulation of light: collecting the light-rays reflected by an object so that they form an image of that object on a surface prepared to receive and record it. Thus the real starting-point for a study of any form of photography is an understanding of light itself, of the means used to make it form images, and to record them. From that foundation one may then proceed to a study of the apparatus used to make cinematographic pictures; thence to the actual technique of the making of such pictures, and to the editing and perfecting of such pictures, once they are made; and finally to their reproduction before an audience.

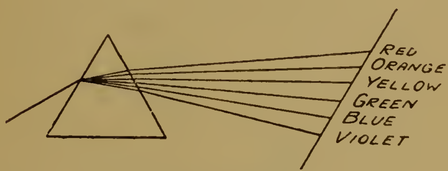
I.

Light and Lenses.

Light, as most of us will recall from our high-school Physics lessons, is scientifically defined as an electromagnetic wave-motion of an almost infinite range of wave-lengths and vibrational frequencies. These light-waves are of the same nature as radio waves, but much shorter, and vibrating at far higher frequencies. In the visible range of light they range from a wave-length of about 0.0004 mm. and a frequency of 715,000,000,000,000 per second for the violet, to about 0.0007 mm. and 442,000,000,000,000 per second in the red, while the so-called "invisible light" frequencies extend beyond both of these limits. These things may not appear to have much to do with making snapshots—but they do, for the visual effects known as color are due to the differing frequencies and wave-lengths of the light-waves.

In free space all light waves travel at approximately the same speed, which is 186,300 miles per second; but in water, glass, crystal, and the like, the waves travel at differing speeds. When a beam of light passes from one medium to another, it is bent, according as it travels faster or slower in the new medium. This is known as *Refraction,* and is the cornerstone of all optics. Since the amount that light bends upon entering or leaving a medium depends upon its velocity in that medium, and since that velocity differs with the different frequencies, naturally a beam of white light, which is a mixture of all frequencies, will spread out according to its component frequencies. Since the different frequencies produce different color-sensations, naturally the resulting band is varicolored. This phenomenon is scientifically known as *Dispersion.*

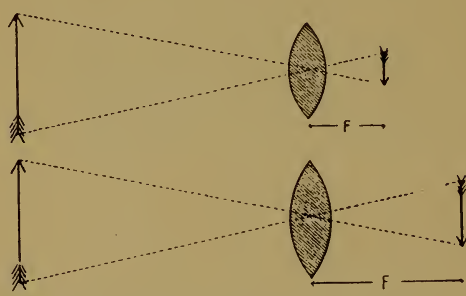
Lens action is based upon these two principles, especially upon refraction. Since light travels more slowly in glass than in air, naturally if we put in the path of a beam of light a symmetrically curved block of glass that is thickest in the centre, the outer edges of the beam, having less glass to traverse, will be bent toward the centre, and eventually will converge at a focal point somewhere along the centre-line of the beam. At that point an image of the beam's source will be formed, and if we place a screen, or a sheet of white paper at that point, the image will be visible upon it. If, however, the block of glass (or lens, for we may as well call it by its correct name) is thinner at its centre than at its edges, the reverse



Dispersion.

will occur, for the light at the edge of the beam will be retarded, that in the centre will get ahead of it, and the beam will bend outwards instead of inwards—be spread out instead of concentrated. Plainly such a lens cannot form a real image, though if one looks into it a visual image will be seen, enlarged, and apparently within the lens. Both types are used in photography, but the former is clearly the more important type, since in order to make a photograph we must have a real image, which can only come from a converging, or *positive* lens. Such a lens is always distinguishable by the fact that, regardless of its curvature, it is invariably thickest at its centre. The second type is called a *negative,* or diverging lens, and is always thinnest at its centre. When used alone, a negative lens produces only a virtual image, but when used in conjunction with a positive lens it serves to enlarge the real image cast by the positive lens, and the combination produces a larger, *real* image. Therefore most photographic lenses are combinations of both positive and negative lenses, but the curvatures are always such that the resulting lens is predominantly positive.

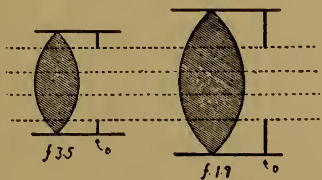
Even in the cheapest hand-cameras, photographic lenses are rarely a single piece of glass. The principal reason for this is the phenomenon of dispersion mentioned above. If the lens were a single block of glass, this action would scatter the various color frequencies of the image. Carried to an extreme, this action would make one image, say of the blue parts of the picture, at one point; another, say of the yellow parts, somewhere else; and that of the red somewhere else yet. Naturally, this would not do. As if to complicate matters, the yellow rays are the strongest visually, while the blue ones are the strongest photographically—and the ultra-violet ones, which are still more potent chemically, are quite invisible. Of course, the divergence of these various images might not be very great—but even a few thousandths of an inch are enough to make a picture look fuzzy. Therefore the lens designers have found it necessary to make their lenses of a number of separate elements of different kinds of glass, with different curvatures and dispersive powers, so designed that they correct each other, and act as a single lens.



How difference in Focal Length of lenses affects the size of the image. In each case, F indicates the focal length: note comparative sizes of the images of identical arrows.

Then, too, a photographic lens must bring all objects, whether they lie directly in front of the lens or far to one side or the other, to a focus on the single flat plane of the sensitive plate or film. If the focal plane of the lens is curved, the picture will be in focus at the centre, but progressively blurry toward the edges. This, too, has to be kept in mind by the designer of a quality lens, as must the problems of completely covering the required picture-area, and of giving an even illumination all over it. Nowadays any good lens will cover its assigned plate, and give a flat field, evenly illuminated. Most of them will even cover a plate a bit larger—but at the cost of quality.

The photographic novice is often bewildered by the term *Anastigmat* in lens advertisements. It really isn't so terrifying, though, for it only means that the lens it designates is free from the defect known as *astigmatism*. Astigmatism is a rather common fault in human eyes and in the cheaper, older lenses. Briefly stated, it means an inability of focus simultaneously on vertical and horizontal lines. In human eyes we correct this by putting on properly curved supplementary lenses (or spectacles) ; in photographic optics we do the same thing, but the correction can be built directly into the lens. Naturally, wherever quality work is concerned, this correction is imperative; therefore all motion-picture cameras are equipped with well-corrected anastigmats. Whether anastigmats or otherwise, photographic lenses are chiefly classified by reference to their *focal length* and *speed.* By *focal length* is meant the distance between the optical centre of the lens and the position of the image formed by rays which parallel its optical axis—that is, rays which come from distant objects. In practical terms it may be defined as the separation of lens and film necessary to bring into sharp focus the images of objects beyond 100 feet distant from the camera. This matter of focal length also serves as an index of the angle of view covered by the lens. Granting the same picture dimensions in each case, the longer the focal length, the smaller the angle of view; in other words, the greater the focal length of the lens used, the larger the image of any given object will be, and the smaller the field included in the picture.



Stop for stop, lens speeds are identical. An F:1.9 lens, (right), closed down to F:3.5 passes the same relative amount of light as an F:3.5 lens at its widest opening.

The *speed* of a lens simply refers to the amount of light it will admit. This depends upon the relation of the lens' effective aperture and its focal length, and is expressed in fractions of the focal length.

While lenses are rated according to their maximum apertures, it is frequently necessary to operate them at smaller openings. Therefore they are fitted with an adjustable iris diaphragm—usually between the elements, and close to the optical centre of the combination—which may be opened or closed, yet which constantly maintains a circular opening optically parallel to the lens. Naturally some standard scale of values for these smaller openings is necessary, as well as one by which the maximum openings of all lenses may be comparatively rated. Many such systems have been devised, but the accepted standard is that of the Royal Photographic Society of Great Britain. This system makes the focal length of the individual lens the unit, and expresses the opening by its ratio therewith. Thus, no matter what the lens, the stop marked, for instance, f:8, is always relatively the same—$\frac{1}{8}$ of the focal length. Obviously, in this system as the size of the opening increases, its numerical designation decreases. This system is of the greatest value in computing exposures, for, light conditions being the same, all lenses will, when used at the same stop, pass the same *relative* amount of light, and will, with equally sensitive film, require the same exposure. Thus the maximum speeds of two lenses may differ, and so may their foci: but, stop for stop, their speeds will be identical. The only difference will be in the quality of the image; naturally the more highly corrected lens will give the better picture. Thus, while at its maximum aperture an *f*:1.9 lens is far faster than an *f*.8 lens, it is not, if closed down to *f*:8, one whit faster than the other.

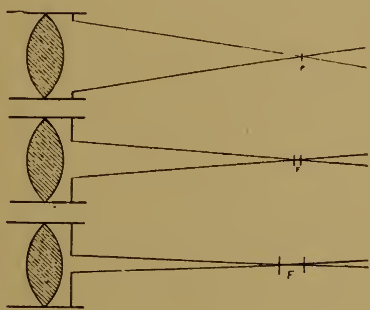
Another important point in which lenses differ is *Depth of Focus.* A fast, highly-corrected lens will only focus sharply on a single plane of an object at one time. However, objects on either side of that plane for some little distance may appear passably clear, though not in critically perfect focus. This range of sharpness before or behind an object is known as *Depth of Focus.* Its extent varies with different lenses and different foci and apertures. It may be considerably different in two lenses of different design but of identical focus and speed. In any case, the depth of focus decreases as the focal length and aperture increase, and also as the object nears the lens. The cause of this is the fact that the light from any given point on an object is, when the lens is perfectly focussed on that object, converged to a point on the film; but the light from any point nearer to or farther from the lens is naturally not brought to a focus at the same plane—*i.e.,* the film,— and thus instead of reaching the film as a *point* of light it reaches it as a *circular patch* of light. This circle is termed the *Circle of Confusion,* and its size determines the comparative sharpness of the image. If the circle of confusion is no larger than 1/250 of an inch, it would seem like a point to an eye over ten inches away: thus, if no point of an object were imaged by a circle greater than 1/250 inch in diameter, the image of that object would appear sharp. In the case of the lenses used in motion picture making, the focal lengths are so short that the depth of focus is very great, so great, in fact, in the case of the lenses used in amateur movie work, that even with noticeably large-apertured lenses, the depth of focus is sufficient to compensate for minor errors in focusing, when the picture is not projected on a very large screen.

Now, at first thought, the question arises, "Why is it necessary to have cinematograph lenses so highly corrected, when the picture is so small?" But that is exactly why they must be so well corrected. A chain is no stronger than its weakest link, and the individual picture on the celluloid strip is not the ultimate goal of motion picture progress, but merely a link in the chain of that progression. The true goal is the living picture on the screen. Essentially, then, the motion picture is not the tiny "frame," but the tremendously enlarged image of that frame on the screen. Therefore the quality of each individual frame must be such as to withstand the colossal enlargement of projection (which, in the case of professional film, may be as great as 1600 diameters) without revealing a flaw, for the slightest defect is magnified just as highly as any other part of the picture. Clearly, then, only the finest of lenses can be used in either taking or reproducing moving pictures.

II.

Motion Picture Film.

But even the finest lenses cannot make a picture alone. They must be used in conjunction with some material that is sensitive to light, and that can make a lasting record of the image they cast. This brings us to the motion picture film itself. There are many kinds of film, but all of them are dependent upon a single principle:



How Depth of Focus increases as the diaphragm opening decreases.

the fact that certain compounds containing silver are darkened by the action of light.

This action has been observed for centuries (it was known even before the Christian Era), but it was not until the beginning of the last century that it was put to practical use. The story of the work of Wedgewood, Fox-Talbot, Daguerre, and the early experimenters is too well known to bear repetition here. Suffice it to say that while the first Daguerreotypes of 1839 required exposures running as high as seven or eight hours, modern sensitive materials have been so perfected that exposures as short as 1/2,800 of a second are possible today.

During this period of development, the greatest problem was finding or evolving a suitable supporting base for the sensitive emulsion. Wedgewood, in 1802, used white leather; Fox-Talbot, in 1839, used paper; while Daguerre, in the same year, used a silver plate. The first great advance, however, came in 1848, when Niepce de St. Victor found it possible to use a glass plate to support his sensitive emulsion. Another great step forward was in 1871, when Dr. Maddox evolved a means for forming his sensitive emulsion in gelatine, with which it was much easier to coat a plate. But the development which made both cinematography and popular still photography possible was the use of celluloid as a film-base, by George Eastman, in 1888. Too much credit cannot be given this development, for without it the motion picture could not have come into being. The sole drawback that this celluloid film has for motion picture use is the fact that it is highly inflammable, for celluloid is a close relative of the well-known explosive, guncotton. This difficulty, however, was overcome a number of years ago when a practically non-inflammable type of celluloid was evolved. It is upon this "non-flam" or "safety" stock that all amateur films are coated, while most professional films are still, for various practical reasons, made upon the earlier nitrate-base celluloid.

Upon these bases there are coated, as far as motion pictures are concerned, two kinds of emulsion. The first is the *negative* emulsion which is exposed in the camera. This is extremely sensitive, or "fast," so that satisfactory pictures can be made in dull lights, and with the very short exposures necessary for moving picture photography. Furthermore, the negative emulsion is made sensitive to light of different colors, so that it will give a true image of all parts of the picture. The other emulsion is known as *positive*. It is upon this that the prints used in the theatres are made from the negatives. Since for this purpose great speed is not necessary (for the printing machines have powerful lights, and need not work as fast as the camera must), the positive emulsion is comparatively slow; and as it is generally used only in the printer, it need not be made color-sensitive. However positive film is sufficiently fast so that in an emergency, where the light is strong, and in the making of titles, etc., it can be used in the camera.

The negative emulsion is in turn divided into two classes, according as it is more or less color-sensitive. It will be recalled that the first experiments made with silver salts and light showed that the silver compounds are normally affected hardly at all by red light, only moderately by yellow or green, and very powerfully by blue and violet. Unfortunately this is entirely different from the visual strength of the same colors. The problem then was to get an emulsion which saw color more nearly as our eyes do. The first successful step in this direction was the *Orthochromatic* emulsion, which was made by treating the silver solution with various dyes which increase its color-sensitivity. The name *Orthochromatic* is derived from two Greek words meaning *True Color*. This was rather pretentious, for the orthochromatic emulsion, though a great step in advance of what had gone before, did not by any means render *all* colors truly. This can be easily proven by taking a snapshot of any subject where greens, blues, reds and yellows are contrasted. Ordinary film is Orthochromatic—but it does not show these colors in their true relations.

The next step forward was the introduction of the *Panchromatic* emulsion. This is also the result of treating the emulsion with various dyes (the ones that the chemists know as the Isocyanines), which have the property of making the emulsion sensitive to every color. The inventor of this went again to the Greek for a name, and chose, most appropriately, two words meaning *All Colors*. Sc far superior has this Panchromatic emulsion proven, that today at least 98% of all professional films are photographed upon it. But its applicability is by no means confined to the professional field: Panchromatic film is no more difficult for amateur use than ordinary film, yet it gives vastly better results; therefore all amateurs who have quality work at heart should invariably use it.

But panchromatizing, though it makes the film sensitive to all colors, does not change its preference for the powerful blue and violet rays: therefore, if we want to get a really accurate rendition of the color-values our eyes see, we must in some way hold back some of these powerful blue rays, and give the weaker greens, yellows and reds a chance to work on the film. For this we use small pieces of yellow-colored glass or gelatine called *color filters*, which are mounted so that they can be slipped onto the lens of the camera. The better grades are so made that they not only retard a large part of the blue radiations, but completely absorb the invisible utra-violet frequencies. Now in order to work under all conditions, we must have a variety of filters: some that hold back only a little of the blue, and others that hold back a great deal of it. Therefore filters are made in several grades, the light-colored ones holding back only a moderate part of the blue, while the darker ones hold back more and more of it. However, no commercial filters hold back all of the blue rays, for that would be as serious an exaggeration in its way as in the original condition the filter is intended to correct.

Now, when these filters are used, it will be seen that they are removing a portion of the light (and the most active portion, at that), *but they are not adding anything to take its place.* Therefore, in order to keep the exposure correct, a larger amount of light must be admitted to the film: *and this increase must be directly proportional to the amount of blue light cut out by the filter.* There are two ways of doing this: either the time of exposure may be lengthened, or the lens opening increased, allowing more light to pass. In amateur movie apparatus the time of exposure is usually fixed, so the compensation must be made with the lens. In order that this compensation may be made easily and accurately the manufacturers have determined what is known as the *filter factor* for each of their different filters. This is the figure by which the normal, unfiltered exposure is multiplied to determine the proper exposure with the filter. This is an unfailing guide to correct exposure when using that filter.

Now one of the great obstacles that always stood in the path of popular amateur cinematography was the cost, and a large part of the cost arose from the fact that first the negative film had to be purchased, then developed, then positive had to be bought, and a print made on it from the negative. Such a system is all right when there are hundreds of prints to be made from a negative for theatrical use, and where, as the saying is in the studios—"film is the cheapest thing on the lot," but it is needlessly extravagant for the individual who may want only one or two prints of his film. To meet this need the so-called "reversal film," which is now the standard for personal use, was evolved. This film is made with both Orthochromatic and Panchromatic emulsions, and its advantage lies in the fact that it serves at once as negative and print. In other words, the film that is used in the camera is by means of a special process, reversed into a positive image, or print, and can be used in the projector. Naturally this cuts down the expense tremendously. While the various manufacturers choose to be very reticent about the actual processes by which this reversal is accomplished, the principle is undoubtedly the same as the process long used by professional cinematographers for emergency work when but one print was needed, and that quickly. In normal development it is always noticeable that when the development is complete, there is still a large quantity of creamy, unaffected silver left in the emulsion, which must be removed by the "fixing bath" of sodium hyposulphate.

Now in the reversal process this unused silver is utilized: after the negative is developed normally, the film is exposed to a diffused, white light until this remaining silver deposit is visibly greyed. Then the developed silver deposit forming the original negative is chemically destroyed, and the print which has just been made from it upon the unused silver is developed, fixed, and washed in the normal manner. This is the essential principle used in the modern "reversal film" processes, though in detail some of the manufacturers' processing methods may differ from this a bit, and due to long and painstaking research into the chemistry of reversal emulsions and the details of the process, the modern reversal film gives immeasurably better results than could be obtained with the ordinary negative or positive emulsions and the crude reversal here outlined. Yet, since no single product could be expected to meet all the requirements of a field so vast as that of 16 mm. cinematography, many of the film manufacturers supply both the reversal film and the normal negative-positive system for the individual to choose from.

There is little or no distinction between the two as to quality, but only as regards their purpose and cost. Where but one positive is needed, the reversal process is immeasurably the better, by virtue of its greatly reduced cost. Furthermore, reversal positives can be duplicated with very fair success, so that the user of the process is not absolutely restricted to having but a single print of his picture. If, however, he wants a great number of prints, or if the subject is of such importance that it seems best to preserve a master film of it for the future, the negative-positive system is of course the best, for a reprint made by this system is essentially an original, while a reprinted reversal positive is only a copy, and loses much of the

The Spirograph Film-Record, an early attempt at home-movies with the "frames" arranged spirally on a disc.

fine gradation present in the original. In cinematography as in art, an original is always preferable to a copy.

Now, while the reversal process has done a great deal to cut down the costs of amateur cinematography, the reduction in the size of the film has done at least as much. It is easy enough to say that a smaller film-size will cut down the expense of filming, but it is quite another thing to establish a world-wide amateur film-standard that will survive long enough to be of practical value to both producer and consumer. One of the chief technical reasons for the world-wide success of the motion picture is the fact that very early in its history a definite standard width of film was accepted all over the world. This standard gauge was 35 millimetres, or 1.375 inches wide, and it is today the accepted theatrical standard the world over. Thus a professional picture made in any part of the world can be shown on theatrical apparatus in any other place.

This same standard width was at first the accepted standard for home movies as well, but as this field developed, there came many attempts to popularize a separate standard for it. Probably the first reason for this move was the idea of safeguarding the professional producers and exhibitors. After the introduction of the non-inflammable acetate-base safety film by Pathe Freres, about 1912, there was a far more important reason for a separate amateur standard: that of keeping the highly inflammable nitrate-base film from being used in the home. Since the war, as the amateur movie field has become more and more important, and better understood by the manufacturers, a further and vital consideration has been added to these two: the reduction of cost.

Thus, while the standard for professional use has been constant at 35 mm., a number of amateur standards have come and gone. There have been many experiments with tiny pictures arranged spirally on wide, endless bands, and on various sized discs, but these have been short lived because they did not cater to the amateur's inevitable desire to control things himself. You can't edit a phonograph record; similarly, in these disc and endless band systems you had to take what you were given, with no chance of rearranging it to suit your own ideas.

One of the earliest and most successful of the true amateur film standards was that established by the Pathe Freres with the introduction of their Pathescope safety film system in 1912. This film was 28 mm., or 1.102 inches wide. It was, therefore, very close to the professional standard size, but with one outstanding difference: there were but two perforations to the frame on the right-hand side, though there were the conventional four per frame on the left. This arrangement facilitated threading and insured automatic framing in projection. In 1918 the Society of Motion Picture Engineers officially recognized a companion standard to this, the S.M.P.E. "Safety Standard," which was identical with the Pathescope standard except that its perforation was conventional.

These two standards, while suiting the first two requirements, took little heed of the third—economy. There was naturally some saving, inasmuch as the Safety Standard had a frequency of 20 pictures to the foot as against 16 for the standard, and that the stock itself was slightly narrower. But there was no reduction of cost to a degree sufficient to appeal vividly to the average amateur. The next experiment, conducted both here and abroad, was to slice the standard stock in two, giving a film 17½ mm. wide. The outstanding exponents of this system were the Ernemann *Kinette* in Germany, and the *Movette* Camera here. This drastic cut in film width cut the cost almost proportionately, but still retained the duplicated expense of the negative-positive system. This difficulty was not overcome until about 1923, when the Eastman Company brought out its 16 mm. reversal film and the famous Cine-Kodaks. This cut costs with a vengeance. While in the standard film system the minimum cost for materials and processing is 10c per foot, in the 16 mm. system it is only 6c per foot. These figures only tell half the story, however, for due to the fact that the standard film contains 16 frames to the foot, where the 16 mm. contains 40, a foot of 16 mm. film is equal to two and one-half feet of standard. Therefore the 400 ft. reel of 16 mm. film is equal in screen time to the 1000 ft. standard reel. Both last about 11 minutes on the screen: but the 16 mm. reel costs but $24 whereas the standard one costs $100.

At the same time that Eastman brought out this revolutionary system, Pathé, of France, brought out an equally startling one. The Pathex system also uses a reversal film, with a frequency of 40 frames to the foot, but the film is only 9.5 mm. wide. This saving in width is due to the use of a slightly smaller picture area, and, principally, to the fact that the perforations are single, and at the centre of the film, between the frames, rather than at the edges. The actual cost of this film is approximately the same as that of 16 mm., but it has one advantage in that the film is sold in shorter lengths, which consequently makes the individual loading cost less. On the other hand, of course, one must load more frequently; but there is a great deal in favor of using the shorter lengths, especially as no scene ever need run longer than ten or fifteen feet at the very most—and none could possibly need the full 26 feet held in a Pathex charger.

The latest development is *Kodacolor*—home movies in *natural color*. This process is so simple that there is no difficulty at all connected with its use, yet it is so perfect, scientifically, that it gives

Today's Standard Film-sizes (actual size). Left, the 35mm. professional standard. Centre, the 16mm. Amateur Standard. Right, the 9.5mm. Pathex Standard.

undoubtedly the truest color rendition of any cinematographic color process—professional or amateur. To understand its workings, we must first look briefly into the nature of color. As we know, the effect known as color is produced by light of differing wave-lengths and differing frequencies of vibration. Now, although the number of different degrees, or shades, of color is almost unlimited, scientists have found that they can artificially produce practically all of them by properly combining the three basic, or *primary* colors: red, blue and yellow. These three correspond to the three units by which our optic-nervous system perceives color. If all three of these nerves are excited equally, we get the sensation of *white;* if they are affected inequally, we get the color-sensation corresponding to a proportionate mixture of the primary colors. Thus it will be apparent that if we can make three photographs of an object, each one so filtered as to record exactly the proportion of the color-frequencies of the total light reflected from the subject that one of these three nerve-units would get, and then in some way combine the three pictures, each having been colored its appropriate color, we ought to get an exact reproduction of the object in its original color. This is the idea behind all forms of color photography. In actual practice it has been found possible to use only two color-images—the red and a blue-green. Of course the loss of the blue means a loss of absolute fidelity in color representation; as, for instance, in the case of white, which is rendered as pale yellow; but it also brings a considerable degree of mechanical simplification. Therefore, all of the commercial color-processes, such as Technicolor, Multicolor, Harriscolor, and Vitacolor, are two-color processes. Kodacolor, on the other hand, is a true three-color process.

In its operation, Kodacolor is somewhat analogous to the still photographer's "screen-plate" systems, such as the Autochrome and Paget plates. In these systems the color-separating screens are embodied in the plate itself, in the form of minute, colored starch grains, or finely ruled colored lines. These break the picture up into tiny parts, each taken through one of the tiny filters. If the filters are small enough so as not to interfere with the vision of the picture as a whole, they make it a color picture. This principle has been in use in still photography for many years, but until lately it has seemed impossible to adapt it to cinematography.

In Kodacolor, however, the system has been applied to home movies. In it, the color filters themselves are placed on the lens of the camera, like any other filters. Then on the film is embossed a series of lenses which form images of these filters on the emulsion, (in all screen-plate processes the emulsion is at the far side of the support—plate or film—from the lens), giving practically the same result as the tiny filters of the screen-plate. Then, when the film has been developed and reversed in the usual manner, projection with similar color-screens on the lens of the projector will give a naturally colored picture on the screen. The lenses embossed on the film can be either spherical or cylindrical. If they are spherical, the filters must also be circular, and the result on the film is like the tiny, round color-dots of the Autochrome plate. If the lenses are cylindrical, the lens-filters must be in the form of parallel strips, and the result is like the microscopic color-rulings on the Paget color-plates.

In Kodacolor, the lenses are cylindrical, running the entire length of the film, and are about four times narrower than the dots making up the average magazine illustration. They subdivide the image into tiny, parallel, vertical strips corresponding to the three color strips of the taking filter. The illustration shows this characteristic very plainly. The subject was a child, wearing a red hat, silhouetted against a blue sky. In the enlarged frame shown, note that the lines are alternately dark and light where the red hat is shown (arrow A), allowing the projection light to pass through the film only at those parts where it will pass through the red filter. In the area representing the blue sky, the lines are still alternately light and dark, but they appear to have been displaced laterally from their

Picture on Kodacolor film of Child with red hat against blue sky, and enlargement showing line composition. Note displacement of hat area (a) compared with sky area (b).

position in the red area, (arrow B), so that the light is now focussed only through the blue filter. When the picture is projected, these opaque areas of the film prevent the light from coming through the corresponding color filter on the projection lens, and falling on the screen. For each color, therefore, the emulsion areas, whose density is determined by the exposure given in the camera and the subsequent reversal process, regulate the amount of light transmitted through the red, green and blue segments of the filter on the projecting lens and thus determine the color which is produced on the screen; so that on the screen we obtain a reproduction of the scene photographed and of its original colors.

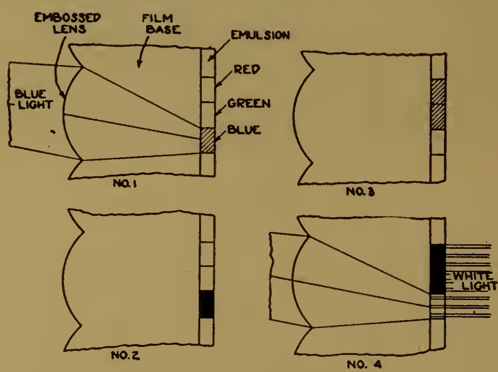
Now, from this it must be clear that the Kodacolor optical system—the taking lens; the filters on it; the lenses embossed on the film; the projection lens; its filters; and the condenser that focusses the beam of the projector's lamp on the film, must all be parts of a perfectly interlocking optical system. If any one of them is changed, the balance of the whole is thrown out. *Therefore, Kodacolor pictures can only be made on Kodacolor film, with lenses of the proper Kodacolor formula, and with the Kodacolor taking filters; and they can only be projected with projectors using the proper optical system, and fitted with Kodacolor filters.* Taken or projected otherwise, they would be only common, black-and-white pictures.

The Kodacolor filters remove so much of the light that Kodacolor can only be taken in the brightest of light, and with the lens working at its widest aperture—*f*:1.9. Incidentally, diminishing the aperture of the lens would alter the relative values of the filter segments, so that the lens *must* be used wide open. To prevent overexposure in exceptionally brilliant lights, special "neutral density filters" are supplied: these reduce the amount of light passing through the lens just as ordinary light-filters do, but they do not alter its color-balance, as color-filters do. A safe rule for exposure in Kodacolor is never to attempt a Kodacolor picture except in lights where, for black-and-white you would use *f*:8—and, in lights where you would use a smaller aperture than that, to use the N.D. filter for Kodacolor.

III.

The Motion Picture Camera.

Even as cinematography is merely a refinement of still photography, so is the cinema camera merely a refinement of the familiar



Illustrating the action of the embossed lenses and filters on Kodacolor film. No. 1, exposure (blue ray). No. 2, Developed image. No. 3, reversed image. No. 4, Projection.

still camera. Reduced to its essentials, a still camera consists of three units:

1. A light-proof box to contain the sensitive film or plate.

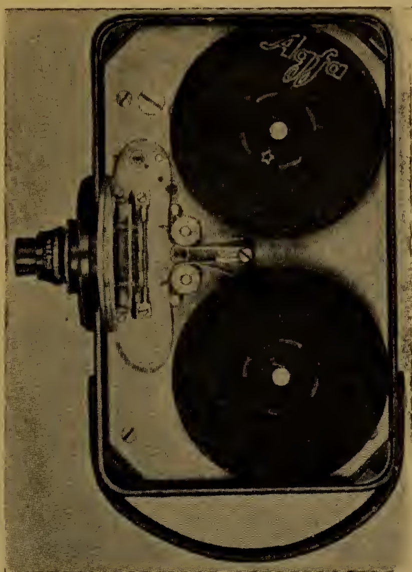
2. A lens to form an image upon the surface of that sensitive film or plate.

3. A mechanism to intercept the beam of light cast by the lens, opening only at the moment of exposure.

To this the cinema camera adds two further units: a mechanism for moving the film so that the individual pictures which compose it are made successively and are accurately spaced on the film; and a mechanism for synchronizing this movement with the opening and closing of the shutter.

To meet the latter requirement, the shutter in a motion picture camera is generally in the form of a revolving disc, with a segment cut out of it. The shaft upon which this disc rotates is then connected usually through a train of gears, to the film moving mechanism, in such a way that the film cannot move except when the shutter is closed.

To meet the former requirement, there have been any number of interesting designs evolved, but the exact details of them are of more interest to the engineer than to the average man who uses a movie camera. However, in some points they all coincide. In the first place, they all require that the film be mechanically designed to be moved through the camera uniformly and accurately: hence the familiar perforations along the edges of the film. These little holes are made according to definite, universally accepted standards as to size, shape, and placement so that the film will fit all cameras, printers, and projectors, and be moved accurately in each. In the camera there are usually two separate agencies used to move the film, because there are two distinct types of movement required of the film. First there is the simple, continuous movement out of the supply compartment and then again into the take-up compartment



A Typical Amateur Camera. (The Cine-Ansco). Note arrangement of mechanical units, also the loops.

after exposure. Then there is the necessarily intermittent movement past the exposure aperture.

The continuous movement is, in most designs, achieved by the simple expedient of bringing the film from the supply compartment over a sprocket whose teeth mesh with the perforations on the film, and then, after passing the exposure aperture (where the intermittent movement is, of course, necessary), passing it back to the take-up compartment after passing under the same master-sprocket; the take-up compartment having, of course, a reel or spool of some sort driven by gears or belts from the master-sprocket shaft.

The intermittent movement is usually given the film by a pair of claws placed either by or just below the exposure aperture. These claws pull the film down the required distance, and then disengage the perforations while the exposure is being made, and return to their highest position to pull down another bit of fresh film. Some designs place these claws in front of the film, while others place them behind it; the exact location is immaterial so long as they move the film accurately, quickly, and without undue strain. Naturally, the less time taken in moving the film, the more time can be given in exposing the picture: but this speed must be governed by the practical consideration of long life to both film and camera. The speed with which this can sometimes take place, however, is indicated by the fact that in one popular super-speed 16 mm. camera, when photographing at the rate of 64 frames per second (four times normal), *the film reaches a speed of nearly nine miles per hour, with its stopping and starting period 1/320th of a second apart.* In order that the film may travel in a straight path, and with as little friction as possible, it moves through a channel made of highly polished stainless steel or bronze, machined to within a very few thousandths of an inch of the film dimensions. Very often this is partly cut away, too, so that the only points of contact are along the sides of the film, along the perforations. In this film channel is cut the aperture through which the film is exposed, which opening governs the size and proportions of the individual "frame." In order that the film may be absolutely flat against the aperture during the exposure, there is a pressure-plate held against it by spring tension, but so designed that it will swing clear of the aperture, gate-wise, when the camera is being loaded. The intermittent movement is one of the most vitally important units in the camera, for unless it does its work accurately, the picture on the screen will not be steady. Realizing this, most of the manufacturers of amateur cameras maintain remarkably high standards of accuracy for the movements of their cameras, while some of the professional designs are so amazingly accurate that film can be run through them, forward and backward, a dozen times or more, without varying the breadth of a hair.

Now there must be some sort of compensation between the intermittent movement at the aperture and the continuous movements at the feed and take-up sprockets. This compensation is afforded by allowing a few inches of slack, called *loops,* just above and just below the film channel. *Without these loops, motion pictures are impossible.* These two little loops, incidentally, were the cornerstone of the power of the famous "Film Trust" of the early days, the Motion Picture Patents Company, which, by virtue of controlling all of the basic patents on moving picture equipment, held the entire industry in a vise-like grip until it was finally overthrown by William Fox in 1913.

The next question that arises is, "Where does the power to drive the camera come from?" Until recently, the answer to that was, "From the cameraman's strong right arm!" The early cameras were all hand-cranked, and the tradition persisted until the coming of sound necessitated motors. Several manufacturers, it is true, marketed auxiliary electric drives, but they were not so generally accepted as to be the rule until within the last year or so. The same course was followed in the field of amateur cameras. Almost without exception, the early amateur cameras were designed for hand drive. But, although it is not excessively difficult, smooth, even hand cranking is quite a trick.

The speed of the crank must not vary between the parts of its revolution, nor must it be allowed to accelerate or decelerate in sympathy with the action being photographed, for every variation in cranking-speed means a variation in the even succession of the individual pictures, and a consequent jerkiness, or change of tempo on the screen. But the tradition of hand-cranking was hard to kill, and even the original 16 mm. camera—the Model A Cine-Kodak—was made for hand drive, with a motor only as a costly auxiliary. But about the same time it was introduced, another firm introduced a motor-driven 16 mm. camera: and the reaction of the public was so tremendously in favor of the easier, motor-driven camera that today amateur cine cameras are practically all motor-driven; and of the scores of models on the market, only three permit hand-cranking in addition to the motor-drive.

This adaptibility to hand-power is a very useful feature for scientific and advanced amateur work, though it is hardly necessary in ordinary amateur use. The motor-drive, on the other hand, is a very important factor in the success of amateur filming, for it enables anyone who can hold and sight a camera to get smooth, even pictures. In addition, it is a great advantage in exciting work of any sort, for a clock-work motor is one of the most unemotional things in the world. No matter how thrilling the action may be, the motor, unmoved, will go on exposing just the proper number of frames per second as long as the release is pressed.

The speed at which a scene is photographed—that is, the number of frames exposed per second—has a direct and important bearing on the accuracy with which the movement is reproduced on the screen. The normal standard speed for both taking and projecting is 16 frames per second. It is easy to see that if the picture be taken and reproduced with the same number of frames passing through the apparatus each second, the movement will be perfectly reproduced. If, however, the camera is slowed down so that but eight frames per second are photographed, naturally when the film is projected at the standard speed of sixteen frames per second, the action will be speeded up, for but half the normal footage of film would be exposed to record any given action, and being projected at the normal speed, would last but half the time the action actually took.

Conversely, if the camera is operated faster than normal, the action on the screen with normal projection is proportionately slowed down, for by virtue of being recorded on, say, twice the normal footage of film, the action will be "stretched out" on projecting, to twice the time it actually covered. Therefore it is obviously important, if we want natural effects, to be sure that our cameras and projectors are operating at normal speeds. On the other hand, of course we can, for scientific purposes, reduce the speed of extremely fast motions, or accelerate extremely slow ones.

We can, if we speed our camera fast enough, see a bullet float gracefully out of a gun, or a bursting soap-bubble drift slowly apart. If, on the other hand, we separate our individual exposures sufficiently, we can in a few moments' time watch the slow growth of a tree, a flower, or a building. These same effects can be used equally well to heighten comedy scenes; as most of us can well remember, the early producers found this out, and worked it for all it was worth—yet such scenes are still amusing.

Another important field of experimentation is the fascinating field of *Animation*. This is the process of making drawings and inanimate objects move by photographing them one frame at a time, and moving them slightly between each exposure. The resulting film is a series of progressively differing still pictures of the motion of the object which will, when projected normally, give the illusion of a normal moving picture of the drawing or object in motion. This is the method by which all animated cartoons—such as *Felix*, and the like—and pictures of animated dolls, sculpture, etc., are made.

The prime requisite for this work is a camera which can be made (either by hand-turning, or by motor) to expose a single frame at a time. For animated figure work, the photography can be carried on outdoors, or anywhere. The lighting in such work, naturally, is exactly normal lighting, etc., in miniature. The animated drawing and cartoon work, on the other hand, is best done indoors, by artificial light. The light-source does not greatly matter, so long as the light is distributed evenly over the field, but Cooper-Hewitt Mercury-vapor tubes are most frequently used professionally, due to their even light and because they do not radiate heat. In animated cartooning, a drawing is made on paper of the background, and those parts of the figure which do not move. This is centred on both drawing-board and photographing-stand by means of a pair of holes which fit accurately on registering-pegs. The parts of the figure which move, are drawn on similarly perforated sheets of clear celluloid, and placed over the paper drawing. If there are any of the lines of the background which show through the wrong parts of the "cell," the drawing on the cell is backed with Chinese White. With good illumination, as many as three cells can be used at once for different moving parts. The cells and paper are held flat during exposure by a piece of plate glass in a hinged frame.

IV.

Making the Picture.

In practical terms, cinematography consists of properly combining these three elements: the sensitive film, the camera, and light. It is far more than merely knowing how to put a roll of film into a camera, and pressing a button; anyone can do that, but it takes cinematographic skill to combine these three elements so that the resulting picture is technically satisfactory, artistically pleasing, and mentally interesting. The modern amateur movie cameras have been so skillfully designed that, if given half a chance, they will invariably turn out pictures that are photographically acceptable; but this mechanical perfection cannot guarantee pictures that are pleasing to look at and interesting to watch. The operator must do that.

Every camera maker provides his purchasers with excellent, detailed instructions on how to load his particular camera, and furthermore has usually designed his camera so that it will not operate unless it is properly loaded. Moreover, in the matter of exposure, which strangely seems to worry so many amateurs, the camera maker has in practically every case put an extremely accurate, simple exposure-guide right on the camera itself. The answer to almost any question on exposure, then, is right at the user's fingertips, if he will but take it. Yet, if he still needs help, there are a great variety of exposure meters ready to help him. Some of them are hardly more elaborate than the guiding tables already engraved on the cameras, but they represent the condensed results of many years' experience, and are accordingly valuable. Others, like the *Watkins* and *Milner* meters, measure the strength of the source of the light, but do not take into consideration the reflective power of the subject. The most useful, and the nearest to infallible among the exposure meters, however, are those which actually measure the light reflected from the subject. These—such meters as the *Cinephot* especially—are probably the safest known guide to accurate exposure under all conditions. Naturally, there are times when printed tables, and even practical, personal experience, are not enough: in these cases the value of a meter that will actually measure the light reflected from the subject is tremendous.

Focussing an amateur cine camera is also an easy task, for the remarkable depth of focus of the short focal length lenses used in such cameras will often compensate for minor errors, and this depth of focus increases rapidly as the aperture decreases. There are times, however, when extremely accurate focus is important. Close-up scenes require care in focussing, as do all scenes in Kodacolor, since this process demands that the lens be used at its extreme aperture of *f*:1.9, at which aperture the depth of focus is at its minimum. In such cases there are three ways of accurately getting a focus: the first is through the use of a tape-measure, after the fashion of professional cameramen; the second is through the use of one of the various distance-meters. Of these there are several types: the simple, pendulum type, like the British *Primus* meter, and the optical range-finder type, like the *Heydes* and *Leitz* meters. Lastly there are the various devices which enable one to actually check the focus of the lens used, on a ground-glass screen, as in a still camera. At the present writing there are only two 16 mm. cameras which have such a feature embodied in them, but there are several devices on the market by which the same thing can be done with any camera. Some of them, as the *Filmo* and *Ensign* focussers, require that the lens be removed from the camera, and thus give only an approximately accurate check on the focus; but others, like the *Heintz* and *Goertz* micro-focussing tubes, keep the lens in the identical position it will occupy in photographing, and thus permit extremely accurate focussing, and arrangement of the composition.

After these important, but rather elementary considerations, comes the question of holding the camera. Many cine cameras are provided with finders which will permit the camera to be used either at eye level or at waist level. As a general rule, the higher position is by far preferable, as it gives a more natural perspective, and allows an easier and more accurate centering of the image. But in any case the camera must be held steady. When using the camera at eye level, it should be held firmly against the face, supported by both hands. It is somewhat a matter of choice as to whether or not the elbows should be braced against the chest, but it certainly gives increased steadiness; the feet, too, should be planted firmly, and well apart. The camera should be held level at all times, and should not be moved except when absolutely necessary, and then in only one plane at a time. Moving it up or down is technically called *tilting*, while moving it horizontally is variously called *panning*, or *panoraming*. In any case, when panning, one should pan himself, pivoting from his waist up, rather than swinging the camera about with the hands. Excepting in exceptional cases, never mix a pan and a tilt, and always be sure that pans are made only when the camera is absolutely level at every point of its travel, and that the pan is made without any vertical motion whatsoever. And above all, never pan or tilt fast. Not only is a speedy pan irritating on the screen, but it is difficult to follow, for our eyes cannot focus on moving objects. The only exceptions to this rule against quick panning are cases where the deliberate intention is (for dramatic reasons) confusion, and in cases where the subject is followed and held in focus and exactly centered, while moving against a blurry, indistinct background. But in ninety-nine cases out of a hundred, a pan or tilt should be made slowly—in fact, it should be made even more slowly than what seems *too* slow, for our conception of time is different while peering through a finder and while watching a picture on a screen. For the same reason, scenes should be made comfortably long—even longer than may seem right while the button is being pressed. You can always cut off superfluous footage, but you can't stretch an inadequate scene. Using 16 mm. film, no scene should run *less* than five feet, unless you are attempting a "flash," such as the Russians like to use. But even these are safer made long, and trimmed. A safe rule to adopt is to average twenty scenes on each hundred-foot roll. But to return to our pans, every movement of the camera should be absolutely smooth, for jumpiness and jerkiness are greatly magnified when the picture is projected. Therefore it is always advisable to use a tripod if it is possible. The best camera can't give a steady picture from an unsteady support, and not even the firmest of humans can rival the physical firmness of a five dollar tripod. Notwithstanding the fact that the majority of amateur cine cameras are advertised and sold as *hand* cameras, they can all be used to advantage with tripods. A tripod doesn't add much to the bulk of a cine outfit, but it adds incalculably to the quality of the pictures one makes.

But these things, while important, are only the A-B-C's of cinematography. They must be known and practiced, but they are only a foundation for really expert cinematography.

The chief distinction between good and bad cinematography is lighting. Cinematography is essentially the control of light, and naturally the best cinematographer is the one who knows how to so control the light reflected into his lenses as to get the most perfect and pleasing representation of his subjects. It may come as a shock to the uninitiated to learn that the majority of the great cinematographers of Hollywood have not touched a camera for many years. Instead, they have assistants to actually manage the cameras, while the cinematographers themselves turn all of their attention to lighting and composition. It is not so illogical, though, for after all, their art does not lie in being able to crank a camera better than anyone else, but in knowing more about light and its control than anyone else.

Similarly, it is far better for the amateur who wants to become really proficient in cinematography to master the mechanics of camerawork as quickly as possible, and then devote himself to the study of lighting.

Ordinarily, when we go out of doors by day, most of us pay no more attention to the light than to realize subconsciously that it is daylight. But when we go forth with a camera, we must make ourselves light-conscious. Photographically, there are two kinds of light: *Hard* light and *Soft* light. Hard light is the kind that comes directly from the sun on a brilliant day, while soft light is more like the diffused sort we get on a hazy day. These two kinds of light naturally give different effects photographically. Hard light gives a harsh effect, with deep shadows and angular curves. Soft light gives a flat effect, with very little contrast, and softened angles. Furthermore, the direction from which the principal illumination falls upon a subject has a distinct bearing upon the way it will photograph. Photographically, there are five main points from which light may strike a subject: from behind; from in front; from the right or left side; and from directly above.

We all remember that the instruction books with our first Kodaks told us to always be sure to have the light behind us. This does not hold true for cinematography, for pictures taken that way often look flat, and lack relief. Instead, the corresponding rule for amateur cinematographers should be to have the light coming from one side or the other of the subject—or, in other words, to always have one or the other of his own shoulders pointing at the sun. This gives us a side light, which produces natural shadows on face and figure, and thus gives a more natural appearing picture. As regards the other directions from which the light may come, the camerist must learn when it is wise to break this primary rule, and when it isn't. A top-light, for instance, is definitely objectionable, for it usually casts unpleasant shadows, is often too hard, and is too balanced for pleasing photography. All of us probably remember, too, the dictum against shooting directly against the light. This, too, is removed for amateur cine cameras. As long as the light does not directly strike the lens (that is, the glass surface of the lens), we may shoot against the light. This gives us some of the most beautiful of all effects, as a back-light gives the subject's hair a lustrous glint, and outlines the figure in a pleasing way that adds a sense of depth to the picture. Backlighting can also be very effective in landscapes and seascapes, and full-figure shots. In exposing, it is only necessary to follow the old rule to "expose for the shadows, and the highlights will take care of themselves." Back-

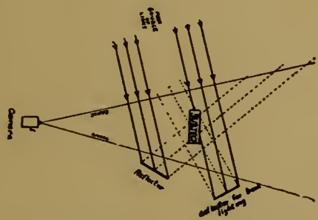
A professional company using reflectors to illuminate action in the shadow of a porch.

lightings are easiest while the sun is still fairly high in the heavens; later, there must often be quite a little thought expended to prevent the sun's direct rays from reaching the lens. On the other hand, backlightings with the sun at such lower angles are particularly effective. Back-lit effects are not feasible for Kodacolor, under any circumstances.

Heretofore we have merely taken advantage of the natural light, without trying to aid it. But studio cameramen long ago found a simple means of aiding and controlling the natural light by the use of reflectors. The simplest sort of reflector is merely a white sheet or a newspaper; but the studio reflector is built on a wooden frame, two feet by four, covered with wall-board. Two of these are generally hinged together to form a single, folding reflecting surface four feet square. As a rule there are three kinds of surface, named after the types of light they reflect. First there is the *Soft* reflector, which is usually coated with a matte white or aluminum paint.

Then there is the *Medium* reflector, which may be coated with a glossy, white enamel or aluminum paint. Lastly, there is the *Hard* reflector, which is coated with burnished tinfoil or aluminum foil. A mirror may be used as a Hard reflector in some cases. Reflectors are also made with gold surfaces, which give about the same correction as a light color-filter when used with Panchromatic film; they are excellent for close-ups, as they give a very pleasing texture to the skin. Small-sized reflectors are also handy in close-ups, as they can be handled much more easily.

The primary use of reflectors is to lighten shadows. But they must only lighten them—never eradicate them. If we use our reflectors to eliminate shadows altogether, we have what is technically termed a "cross lighting," which, being perfectly balanced, is absolutely flat, unnatural and distinctly irritating. *The photographic*



A useful arrangement of reflectors for general use.

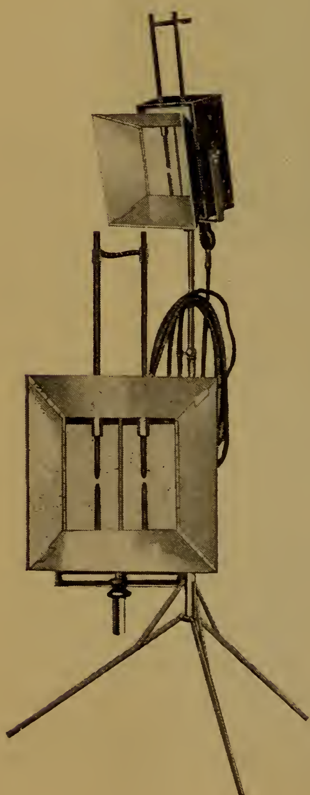
value of the lightest part of the light from the bright side of the subject should be at least twice that of the brightest part of the shadow side. The best way to assure this is to use a monotone viewing-glass: if, without reflectors, the shadows appear black, use reflectors, and with them build your light up to the point where it appears through the filter as detailed as the same shadow looked formerly to the naked eye. Probably the most effective general reflector set-up is one such as is shown in the diagram, with a soft or medium reflector used for the front light, and a hard one for the back light. Such an arrangement may be augmented to take care of as many figures as needed. In such a case, it is a good safeguard to have your actors go through a brief rehearsal of their action while you watch them through your viewing filter, to see that none of them at any time steps out of the reflector area. In cine-portraits, a mirror may often be used as an effective backlight for the hair, especially if it is shaken a bit during the scene, so that a shimmering effect is given. But, when using hard reflectors, one must always be careful not to "hit" the lens with their direct beam, which will fog the film; similarly, do not use a hard reflector to front-light a face unless you have to; its strong light makes unpleasant contrasts, and the strong beam makes most people squint.

Reflectors are especially useful in Kodacolor work. Beautiful effects can be gotten by using a gold one for the sunlit side of the face, and a silver one to brighten up the shadow.

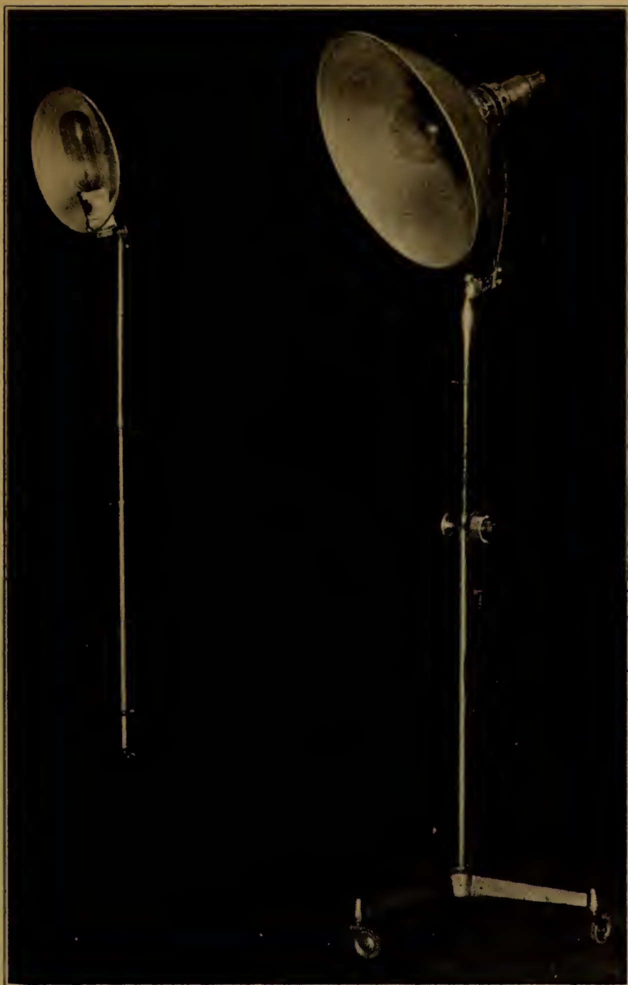
As reflectors add some light to a subject, they permit a slight decrease in exposure; the exact amount is soon learned. Remember, though, when using a reversal film, that a slight underexposure is always preferable to overexposure.

Interior lighting is, in principle, much the same as exterior lighting. The effects upon the subject of the direction, type, and intensity of the light are the same, but the indoor camerist has the advantage of being able to control his lighting to a very fine point. He can put it just where he wants it, and make it as hard or soft as he wishes.

There are two types of lighting equipment available to the amateur: arc and incandescent. The arc gives a harder, more concentrated light, while the "Inkie" gives a warmer, fairly hard glow which, if not quite so intense, is much easier on the subjects' eyes. Due to the fact that the incandescent's light is yellower, it is apparently much more efficient with Panchromatic film than the arc is, and gives more natural skin-tones. However, the introduction of the so-called Panchromatic carbons for the arcs has about evened things up. The arc, however, will always give a harder light than the inkie, because its light-source is so much more concentrated. Either type of light, of course, may be diffused with frosted glass or silk



A typical amateur arc-lighting unit. ("Little Sunny" twin-arc).



A pair of typical Amateur incandescent-lighting units.

diffusing screens: these, however, cut off a portion of the light, and require an increase in exposure.

The angle from which artificial light falls on a subject has just as considerable an effect upon the modelling of that subject's face and figure as does the angle of natural light. There are four important types of interior lighting.

First, there is the plain, flat, front lighting. The effect of this is exactly the same as a flat front light out doors.

Then there is the unrelieved side light. This almost "burns up" one side of the face, but leaves the other a blank shadow. This may sometimes be used handily to heighten certain dramatic effects, but it is naturally unsuitable for general use.

Flat, front light.

Thirdly there is the ¾ front lighting. This is the most useful for general use, as it brings out the modelling and skin texture in the most natural way, particularly when the light-source is high.

Lastly there is the familiar back-light. This should only be used as an accessory to one or more of the other forms, for if all the light comes from behind, the picture becomes a silhouette. The source of a back light should be a fairly intense, hard light; in professional use spotlights are usually employed, because their beams can be narrowed or widened to meet the immediate condition. A Backlight that is moved part of the way toward one side or the other is also known as a rim-light, as it outlines the edge, or rim of the figure, giving a very pleasing effect.

For general use, these lightings should be used in combination; at least two light-sources should be used, even though it is possible

Side lighting.

to get well-exposed negatives with some of the single lighting units available. The added unit or units make it possibe to balance your light even more accurately than you can outside with sun and reflectors. And reflectors, by the way, are, if anything, even more useful indoors than out, for a good supply of them, intelligently used, can make a little light go much farther than would otherwise be possible. In some close shots, for instance, a single unit can be made to do double duty for back and front light, by placing the light behind the subject, and using a hard reflector or a mirror to reflect from it for front light. Similarly, some side lightings can be balanced the same way, by using, say, a medium reflector to prevent the picture's "going flat." Such combinations can be

Back-lighting, with reflection or secondary light to relieve shadowed side.

worked out in great numbers, and are tremendously interesting experiments.

The chief thing to remember in arranging artificial lighting is that normally the effect to be aimed at is not that of *artificial* lighting, but that of natural illumination.

In the matter of exposure, the paramount fact to be borne in mind is that the illumination varies not directly with the distance, but *as the inverse square of the distance.* Therefore, if we get a certain amount of light at five feet from a lamp, we will get only *one-fourth* as much at ten feet. Therefore, do not try to illuminate too large an area, for unless your equipment is large, you will find that you can get far more satisfactory pictures covering a moderate area efficiently than covering a large area weakly. Above all, do not let the visual brilliance of the lights deceive you; their photo-

Three-quarter front-lighting (with source fairly high). A satisfactory arrangement for general use.

graphic strength is quite different, and you will find that, except in close-ups, you will rarely be able to work with your lens stopped below *f*:2 and the camera running at normal speeds.

In using these lights in the home, it is best to connect them directly to the base-board or floor outlets, as they draw more current than the wiring of many ordinary bridge or table lamps can stand. If you are using an arc light which has no switch provided for turning off the current, never use the switches in the house circuits: pull the plug. Otherwise your switch may arc, blowing out fuses and perhaps doing serious damage. Similarly, it is safest to see that the fuses for the circuit are either 25 or 30 Amperes—but no higher. The fuse is the safety-valve of the electric system, and if anything is wrong, it is better that the fuse give way rather than some important and delicate part of the circuit. So when

Excellent dramatic effects can be secured with a single light source. Note effectiveness of shadows. (Courtesy William Fox Studio).

the lights go visiting, a pocketfull of fuses should accompany them. You may not blow any out—but your neighbor's lines may not be fused high enough to stand the load. A trip to the fuse-box doesn't take long, and it may save a lot of trouble.

Returning again to cinematography *per se*, there is the matter of camera angles. This phrase has been overworked by directors, critics, and publicity writers until it has gathered a wide variety of meanings, and become very trite. Essentially, though, it refers to the placement of the camera. It is not enough merely to set up a camera and shoot; there must be a definite relation between the subject, the type of action, and the position of the camera.

The first distinction that the amateur learns to make is between the *close-up*, the *medium-shot*, and the *long-shot*, whether he thinks of them that way or not. Professionally, there are many varieties and sub-varieties of these, but for personal use these three names, rather broadly construed, are sufficient. The *long-shot*, as its name implies, is made with the camera at some distance from the subject, showing the full figure, and a good deal of background, but it may also come close enough to fill the screen with the full figures of the people. The *medium-shot* is but a step from this; the camera brought still closer to the actors, and consequently showing only parts of the figure—say from the knees or waist up. The *close-up* brings the camera still closer, and shows less and less of the figure: it may show the head and shoulders of one actor, or it may

The keynote of all amateur interiors should be naturalness, not the effect of having been made by artificial light.

(Courtesy Paramount-Publix Studio)

even be restricted to a big head. This latter, though, is difficult to make artistically, and should therefore be avoided. It is, too, rather a strain on the actor, unless he is quite experienced, for he must express whatever is desired solely with his facial expression. Besides, the proximity of the camera in such a shot is often disturbing.

These various shots all have their definite places in camera technique, and when properly blended together, add variety to any type of picture. It is always well to open a sequence with a long shot, to thoroughly "plant" the geography of the scene in the mind of the audience. Thereafter, work progressively closer and closer to the object in the scene upon which the interest is centered. Remember that except where the interest is centred on the background, as in travel films, the actors in the scene are the important things: the closer one can get to them, the more clearly their action can be shown, and the easier it is for the audience to understand what is going on. This naturally leads to the conclusion that closeups are desirable. They are. Though in professional films they have been overworked to the point where they are often the refuge of headstrong stars and incompetent directors, closeups are one of the most powerful means of screen story-telling. An intelligently used closeup can tell more than any title, or than double the footage in longer shots. They can centre the attention on any desired object, animate or inanimate. Therefore, use closeups wherever they are logically possible; but don't overdo it. Closeups, rightly used, are a powerful aid to cinematic expression; wrongly used, they are just as great a hindrance. There can be no blanket rule laid down to govern the time when to use or not to use any given type of shot; the only thing that can be said is: always try to get as big a picture of the important action as is possible, but be logical about it. Remember, too, that the nature of the action often determines the type of shot used. A long shot of two children playing in the sand doesn't tell much about their play, nor does a close-up of one player in a football game tell much about the progress of the game. If we are interested in the personal reaction of the player, the close-up is logical; if we are interested solely in the game, it isn't.

But there is much more to camera placement than merely determining the size of the figures. It can also be used to bring about a visual separation of the planes of the picture. If, for instance, we are to make a shot of a young girl in a light-colored dress, it is obvious that she will stand out better against a dark background than she would against a light one. Conversely, if she has on a dark dress, she will stand out better against a light background. Now, oftentimes just a slight change in the camera's position will take care of such details as this. Incidentally, while on the subject of backgrounds, we might mention that it is well for the cinematographer to be sure that his camera is so pointed that none of his actors will seem to have trees, flowers, or telegraph poles growing from their heads, or that they will have any embarrassing relation to action going on in the distance.

The angle at which a subject is photographed has a considerable bearing upon the way the scene will affect an audience. Therefore, before choosing any definite camera angle for a scene, figure out just how you want the audience to react to it. If you want them

Fast-moving objects, such as airplanes, are best photographed coming diagonally into the camera.

to get the meaning of the action with the minimum of effort, shoot your scene "head-on," in the simplest, most ordinary manner; if you want to go in for trick viewpoints, be sure that your action is clear enough to get itself across in spite of having to compete with the photography. As a rule, plan your shots so that the photography helps, not hinders, the action.

The camera angle, too, must be governed by the type of subject and the speed at which it moves. The shutter speed of the average cine camera is not sufficient to get unblurred pictures of fast-moving objects; therefore such scenes as races, airplanes, and the like, should never be attempted with the subject moving directly across the picture. They should, instead, be photographed moving diagonally into the picture, but if possible, never out of the picture, as that is not nearly so interesting a view. Parades, by the way, should invariably be photographed coming into the camera.

This brings us to the important subject of preserving the continuity of movement. In making any sort of a motion picture, all the scenes can seldom be photographed in exact continuity, but through them all the direction of an actor's movement should remain continuous unless the reason for its reversal is shown on the screen. Say that we have a sequence showing Father leaving the house and walking down to the corner store for a cigar. If in our first scene we have him come from the door of the house at the left, cross the scene, and go out to the right, he must preserve that direction of movement in every scene until we see him reach the store and start his return. If he were to be shown in one scene walking from the left to the right, and in the next walking from the right to the left, the audience, regardless of whether or not it had been present at the filming of those scenes, would sense something wrong; the change of movement would confuse them. If, on the other hand he is seen to meet a neighbor who tells him something that represents a definite change of thought and purpose for his walk, he may conceivably be shown travelling in the opposite direction in the next scene, *provided that this new direction of movement is maintained to the end of the sequence. Remember that the audience can only judge directions and motives from what it sees on the screen, and to keep the thought of motion connected in their minds it must be continuously in the same direction on the screen before them, regardless of what it might be in real life.* Similarly, if we want to show two separate movements, and keep them separate, we can do so by the simple expedient of having them move in opposite directions on the screen. Of course, if they are both definitely on the same path, both must naturally move the same way on the screen. To return to our example: if we have shown Father on his way to the cigar store, walking from left to right, and we want to show Uncle Bob going from *his* home toward the same store, it is wiser to show him going from right to left in contrast with Father's progress from left to right. Then, if Mother, mindful of Father's resolution not to smoke, sets out after him, she, too, should go from left to right as he does. In the same way, if an actor leaves one scene from the right, he should re-enter it from the same side, but if the scene is changed, he should logically enter it from the left, to preserve the illusion that his movement between the two places was continuous. He may have swum a channel or flown across an ocean in the interval, but as long as he was not seen doing so on the screen, he has no excuse for not obeying these conventions of cinemotion.

The tempo of such a series of movements should also be constant. It would be incongruous to show Father walking out of his house in the first scene, running down the street in the second, and walking slowly again in the third, unless there were some well established dramatic reason for it. If, on the other hand, he starts out at a walk, and then meets a friend who tells him that his office is on fire, he has a legitimate reason for running in the later scenes. In the same way, lapses of time and space can be indicated by changes in the tempo of a movement. If, for instance, we want to show a person climbing a mountain, or walking a great distance, without devoting a proportionate footage to it, we can bridge the gap by first showing his starting eagerly off at the foot of the climb, and then following this by a scene near the top, showing him dragging himself slowly along, mopping his brow, etc. The same expedient can be used to indicate a rising curve of emotion, too. If, reverting to our first example, instead of a cigar store, it is the local speakeasy that Father is going to, and instead of Mother, we have a raiding squad, we can create quite an emotional effect by merely contrasting the tempos of father's deliberate walk and the speeding police car. If rightly executed, such a sequence can create considerable suspense, but it must be done skilfully or not at all, for it has been overdone so often in professional films that it takes expert handling to avoid being laughable. Still, that is the way with most emotional tricks: properly handled, they are legitimate dramatic effects; overdone or bungled, they make for comedy.

Returning once more to our original example, suppose that Father reaches the cigar-store, and is overtaken by Mother. How is she to enter the scene? There are two chief ways. First, let us say that there are several people standing and walking around in front of the store—not for any dramatic purpose, but merely to help "dress" the set. Now, if Mother is to enter surreptitiously, and pounce suddenly upon her errant spouse, she can do so either in a way that will surprise the audience almost as much as it does Father, or in a way that will let them into the secret in time to chuckle anticipatorily as she approaches her prey. In the first case, she would enter near the rear of the scene and pass behind the various "extras," coming suddenly forward to reveal herself at once to Father and to the audience. In the second case, she would enter near the front of the scene and pass in front of the "extras," for in a picture the commanding position is almost always that nearest the camera. In this case, she could hardly help but be noticed, at least by the audience, and, if it were desired to make her entrance immediately noticeable, but less important than what she did after reaching Father, she could be made to enter fast, and rush across the picture, crossing in front of everybody else, to Father. In order to give her additional prominence, she could also be made to stop just after her entrance, and pause for a brief moment, before hurling herself across the picture at Father. That pause is like a moment's rest just before a crashing musical chord: it focusses the attention on Mother. On the other hand, after she has reached Father, if it is to be *her* scene, Father must not move too much after registering his surprise; but if it is to be *his* scene, she should "freeze" while Father, as the saying is, "takes it big." In any acting, but especially in screen acting, where two people are playing a scene together, the important thing to remember is the definition once given by Joe Jefferson: "When I talk, you listen; when you talk, I listen." That sums up the whole of acting, for movement on the part of the player who, for the moment, is of secondary importance, will kill the scene, no matter how great the other player may be.

This brings another thought: apparently there is some importance in the arrangement of the figures—whether they move this way, or that way, or stand still. Assuredly there is; it is what artists know as *Composition*. This word has a terrifying sound to most amateurs, but it need not have, for, whether they like it or not, they are making compositions every time they take a picture, for composition is merely another term for arrangement. As Victor Freeburg says, "A remarkable thing about composition is that it cannot be avoided. Every picture must have some kind of arrangement, whether that arrangement be good or bad. As soon as an actor enters a room he makes a composition, because every gesture, every movement, every line in his body bears some pictorial relation to everything else within the range of our vision. Even to draw a single line or to prick a single point upon a sheet of paper is to start a composition, because such a mark must bear some relation to the four unavoidable lines which are described by the edges or the paper." Thus, since we are inevitably making compositions, we might just as well make good ones.

A great deal has been said and written about composition, and many scientific theories have been devised to aid in composing pictures: but the most practical rule that has ever been laid down for composition is that given a young photographer, years ago, by that dean of still photographers, Edward Steichen, when he said, "Simply make your pictures pleasing to look at." That is far easier to remember when in the field than the various intricate mathematical and geometrical formulae which have been devised from time to time.

The easiest way to start this is to remember that a photograph, whether still or moving, is essentially an arrangement of lines and masses rendered in monochrome, ranging in tone from black through every shade of grey, to white. Therefore, even with Panchromatic film, do not base your compositional plans so much on the color contrasts you see as on the arrangement of the lines and masses in the scene before you. A great help in this is a monotone viewing filter, but be sure that you don't use the same filter for both Pan and Ortho film! Then, remember that these various features of the composition must be balanced: of course they need not—in fact, should not—be absolutely symmetrical, but they should at least be uniform enough so that neither side is "topheavy." Then, lastly, and most important, remember that the function of composition is to guide the eye to the object of chief interest. Tests have proven that the eye, in viewing a picture, starts at the lower left-hand corner, and moves diagonally upwards to the upper right-hand corner, *if not intercepted.* The function of composition is to either see that the picture is arranged so as to conform to this natural law, or to provide something at the right point along that course to divert the eye to the proper place. This diverting object need not be large or conspicuous: it may be almost anything—a tree, a flower, a rock, a stump, or a bit of furniture; it may be there naturally, or it may be placed there for the purpose by the cinematographer. But to serve its purpose, it must be something that is natural to that location.

Another aid to composition is the contrasting of the different planes. In almost any sort of long-shot, the planes can be easily separated if the alternate ones are either shadowed or highlighted. For instance, in the landscape shown here, the tree shadowed foreground makes the picture much more natural and interesting than it would be if it were all sunny background. This is because the separated planes give the eye something upon which to build an illusion of depth.

All that has been said about composition naturally applies just as forcefully to medium-shots and close-ups as it does to long-shots.

An illusion of depth is created by contrasting a shadow foreground with a brilliantly-lit backgrounl.

If anything, the need for pleasing composition is greater in them than in long-shots.

All of the foregoing must lead inevitably to the conclusion that a motion picture should not be shot haphazardly. Most assuredly it should not. In the professional field there were but two individuals who were successful in shooting silent pictures "from the cuff," as the saying has it—without the guide of a premeditated scenario. Even they have had to reform, since the coming of sound. Why, therefore, should the amateur, who has quite enough technical and artistic handicaps already, try to make his films in the manner exactly opposite to the findings of professional experience?

Of course, in personal film work there must always be a certain amount of impromptu filming, but wherever it is at all possible, the amateur should work from a definite plan. This plan may be merely a mental outline, or it may be a detailed, written script: but plan there should be, anyhow.

In the cases where a definite, written script is possible, this script should be prepared as far in advance as is feasible, and be made as complete as possible. The script should grow out of a brief synopsis of the plot, or action. This is the scenario itself. Then, once this action has been definitely perfected and approved by all concerned, the synopsis should be enlarged to form a *shooting continuity* (commonly called a working script). This is literally a written word-blueprint of the picture as the camera will see it. It should specify every scene, giving the number of the scene, the estimated footage, the camera set-up, the angle, the action, and the type of location. Spoken titles should be included in the script, so that the actors may know what words to speak when making the corresponding scenes.

Before starting the camerawork, there are several definite lists which should be made up, as without them much confusion and loss of time and effort will result. First there is the list of the locations upon which the scenes will be filmed. The locations should be selected in advance, and listed with the scenes to be taken at each, and with the people needed at each. It is also well to note the time of day when the light is right for each scene on this schedule. Then there is the property schedule, which again enumerates the scenes, and lists the "Props" needed in each. Any inanimate object used in a scene is a Prop—whether it be a Rolls-Royce or a can of fishing-worms. In some cases, certain photographic accessories might well be on this list, too. Such a list is vitally important to the work of the chief Property Man, if his very important work is to be done efficiently.

When the picture is being photographed, it is wise to have one individual whose time is exclusively dedicated to keeping track of every detail of the action of the scenes photographed. This person is called the *Script Clerk,* and the job is far from being a lowly one, for it is highly important, and involves a tremendous amount of detail. In making a picture, scene 26, showing the hero leaving his room, may be shot today, while scene 27, showing him leaving the house, may not be photographed until a week later; if there is no lynx-eyed script-clerk to check up on him, he may leave his room in perfect morning costume, with spats, gloves, and a cane, only to leave the house—apparently ten seconds later—in flannels and a tennis-racquet! Such things are constantly watched in professional pictures, but even so mistakes sometimes occur; Emil Jannings, for instance, once grew a very bushy head of hair apparently overnight! Even more remarkable mistakes have been known to occur in amateur films, so the script clerk is almost as important as the director or cinematographer. Besides, this detailed notation is a tremendous aid in keeping entrances and exits from becoming "crossed," and in editing and titling the film afterwards.

Each scene bears a number on the script: that number should be photographed on the film after the scene is made. In the studios this is done by holding up a slate in front of the camera while a few feet of film are ground off. This slate bears the number of the scene and "take" in moveable letters, the names of the director and the cinematographer, and the name or number of the picture. On the back of the slate is painted the self-explanatory legend, "N.G." If the scene is good, one side of the slate is photographed; if it isn't, the other side is used. For amateur use, in place of such slates there are a number of useful devices made, best among which are the scene-numbering note-books made by Bell & Howell and Eastman. These will carry all the information needed, yet they fold up to pocket size. They form a valuable written memorandum of the scenes and their contents for future use, and the numbers are the only quick method of identifying the scenes in editing.

V.

Editing.

After the camerawork on any film, professional or amateur, is completed, the next step is, of course, the development of the film. But, so great is the popularity of the reversal process that very few amateurs nowadays attempt to do their own laboratory work. For those who desire to, however, the requisite formulae, etc., are given elsewhere in this book, so the next step for our consideration is the assembling and editing of the finished film.

Obviously the film must be assembled on its return from the laboratory, for several fifty- or hundred-foot rolls may have been exposed on one connected series of scenes which are to be joined together on one or more four hundred foot reels. Moreover, it is highly improbable that the scenes in even the simplest sort of moving-snapshot film could all be photographed in the exact sequence in which they are intended to reach the screen. This, by the way, is one of the great advantages of making movies on the celluloid strips which are generally used: scenes can be taken in any order and at any time and place, and later joined together in any desired sequence.

The actual apparatus required for this work is simple. The most important accessories needed are a good, firm table, and a pair of geared rewinds. The necessary splices in the film may be made by hand, but this is not to be recommended. Particularly on so small a film as 16 mm. or 9.5 mm., hand-made splices cannot begin to approach the neatness and accuracy of those made with the various machines made for the purpose, and, since these machines are not at all expensive, and since splicing is such an important part of movie making, no amateur should stint himself in the matter of editing equipment. If the budget is limited, it is really wiser to get a less expensive camera, and the *best* of editing equipment, for even the cheaper cameras will do passably good work, and can in time be exchanged for better ones; but the damage done by inferior splices lasts forever.

The actual splice is simple to make, regardless of what method or machine is used. The first thing is to cut the film at the proper place: this cut may be made diagonally, or straight across the film. Then one end of the film is moistened slightly, and the emulsion, which is thereby softened, is carefully scraped off with a dull knife-blade. This must be done very carefully, for all the emulsion must be removed, yet the film-base itself must not be torn nor scratched deeply. This is the reason for using a *dull* blade. The width of the area scraped should not be more than 1/16 of an inch. This scraped strip is then brushed over lightly with a brush dipped in the film cement, and the end of the strip that is to be joined to it placed over it, and the two pressed together for ten or fifteen seconds. The action of the film cement is in no sense that of an adhesive: instead, it welds the two strips together. Film cement is made of various celluloid solvents—usually acetone and amyl acetate. The action of this is to soften the celluloid base of the two films being joined. The pressure forces the two softened surfaces together, and then, as the cement is extremely volatile, the two almost instantly start to harden again, but together, as one piece of celluloid. Thus it can be seen that splicing must be done quickly and accurately, and for this reason especially, mechanical splicers are valuable.

Of course, splicing and editing can be done any place, but if it is possible it is a good idea to have a special cutting table dedicated exclusively to this service. Such a table should measure at least two feet by three. If a series of shelves can be provided at the rear of it, one will have a handy place to store his film while waiting a chance to assemble and edit it. At any rate, one can always use all the available table-space when cutting film. The rewinds and splicer should be permanently mounted on top of the cutting table. For the utmost convenience the rewinder should be supplied with two geared heads, so that the film may be immediately run in either direction. However, one geared head and one dummy are satisfactory. Users of the negative-positive system will at times find a twin rewind system, such as the British *Ensign*, useful, for it enables both the negative and print to be wound and cut together. An opening a couple of inches wide by anywhere from two to eight or ten inches long should be cut into the top of the table. This opening should be fitted with a pane of heavy opal- or ground-glass, inset so that its top is flush with the surface of the table, and with an ordinary 25 Watt light bulb beneath it. This glass is for inspecting the film as it is rewound, and makes selecting the exact place for a cut easy. A cruder, but no less effective inspection glass can be made by merely fitting an ordinary "Brownie" darkroom light with an opal glass, and fitting the whole into a properly-shaped hole in the table. This, however, does not make so smooth a joint, and does not appear nearly so workmanlike. Since the individual frames on substandard film are so small, some sort of a magnifying glass is also helpful in cutting. This may range from the elaborate, illuminated "editers" made by some firms, to the simplest magnifying lens, but in any form, it is a great help.

Another convenient, though by no means imperative accessory, is a large hamper, lined with a cloth bag, and above which is a rack along which are disposed a number of small books, from which several scenes may be hung for quick reference, a whole sequence, perhaps, grouped on one or two hooks. The trailing ends of the film being in the bag (which should be kept perfectly clean), they are protected from dust and dirt, and in a handy place. Film should never be allowed to unroll on the floor; it is too likely to collect

A professional cutting-room. (Courtesy Paramount-Publix Studio).

injurious dirt and dust, and perhaps even be trod upon and badly damaged. As an additional safeguard, it is a good plan to wear light, cotton gloves, as professional cutters do whenever they are handling film. It keeps the hands clean, and prevents finger-printing the film.

With such an equipment one is ready to go seriously about the task of editing the film. Not merely splicing and assembling the scenes, but really *editing*—cutting out all imperfections; eliminating all that is extraneous and uninteresting; and, above all, arranging the scenes so as to get the maximum effectiveness out of the minimum footage. One of the chief differences between amateur and professional films is that professional films are always carefully, expertly edited, while amateur films too often are not. After all, the primal purpose of all pictures—even the most banal snapshots—is to tell some kind of a story. To do this they must be able to arouse and hold the beholder's interest. To hold that interest they must tell their story—whether it be *Ben Hur* or the Baby's bath—as compactly and effectively as possible. They cannot ramble all around Robin Hood's barn and still expect to be regarded as interesting. It is the editor's task to keep them from wandering; whatever their story, they must be made to tell it with the least lost motion. Above all, they must never drag or bore: that is the one unforgivable sin. A picture may have many faults, and still be thought passable—if it entertains. It may be in every other way magnificent—but if it bores it is a failure. Professional films afford innumerable instances of this; every cinemagoer can recall instances of pictures with weak stories that were made interesting by clever editorial treatment, and of potentially great films ruined by unimaginative cutting. Hollywood is full of tales of films made and unmade in the cutting-room.

All of this applies equally to amateur films. Many an amateur library has been discarded just because its owner did not know, or care about proper editing, while, similarly, there are many libraries which have, though not particularly interesting in themselves, been made perpetually interesting merely by clever editing. Thus editing is as important a part of cinematography as good camerawork; furthermore, it offers fully as many opportunities for individual artistic expression. Indeed, the distinctive character of much of the foreign production that is exhibited here is directly traceable to the highly individual styles of their editors. For instance, there are the British films, which so often stress the atmospheric background to the injury of the story; M. Dreyer's amazing use of intercut close-ups in *Joan of Arc;* and the brilliant use of extremely short cuts—flashes—in the Russian films, which, above all, are masterly examples of artistic editing.

The actual operations of editing are not difficult. As in camerawork, the amateur can well take a few leaves from the professional's book. In the first place, the scenes should be numbered. Whether, as in a dramatic production, the number is photographed on the film at the end of the scene, or no, the scenes should each be given an identifying number, roughly indicative of its place in the picture. These numbers should be catalogued, and a *cutting continuity* prepared, giving a definite idea of the contents of each scene, and its place in the primary arrangement of the picture. The original script, and the reports of the script clerk are invaluable in this stage. Then the film should be broken into its component scenes, each scene being made into a separate roll, and a numbered slip of paper attached. All similar scenes should be grouped together. The Hayden editing reels are very useful for this. When all this has been done, the picture should be roughly assembled, the scenes being merely clipped together with paper-clips. Then this assembled film is rewound and inspected, and all imperfections, such as bad frames, partly fogged scenes, N.G.'d ones, etc., being cut out, and the remainder spliced together. The picture can now be projected, and is ready for the real business of editing. This consists of eliminating artistic imperfections as the mechanical ones were eliminated: rearranging the scenes to their best advantage, cutting in others that may be needed, and clipping off all non-essential footage, from a frame to a sequence. This is the time, too, to study the accurate placement of close-ups. Close-ups should never be cut into a scene until the picture has been roughly assembled and projected at least once, so that the editor can make certain of the proper place for each in relation to the scene and to the picture as a whole. Furthermore, the scenes into which close-ups are to be inserted should be photographed straight through, and the close-up made separately. The reason for this is that if such a scene is made in two parts, there is almost inevitably a visible break in the continuity, composition, etc., on the screen. Also, if the scene is made completely, and the close-up made separately, the close-up can be inserted at exactly the right place, while if made otherwise, it can only be placed approximately. Also, if a close-up shows a person speaking, his lips should also be seen to be moving in the accompanying long-shot. If he is speaking a spoken title, to be shown on the screen, he should by all means speak the exact words of the printed title. Incidentally, in cutting such titles into a picture, the editor can "cheat," and save footage, by showing a close-up of the character beginning to speak, cutting to the title, and returning to the last foot or so of the close-up. You need not show the entire action of the speech, for the audience sees the start, then pauses to read the title, and feels it quite natural that when the picture returns the actor is just finishing his lines.

Editing also has an important bearing on the *tempo* of a picture. It can accelerate a lagging tempo, or tone down too fast a one. If, for instance, certain scenes in a sequence requiring rapid movement seem to drag, they can often be speeded up by judicious trimming—cutting them so short that only the vital action of the scene is left; cutting exits as soon as the actor begins to leave the picture, and beginning entrances only when he is well into it. Most important in such sequences is the use of many closely intercut "flashes," for this is one of the simplest and most effective methods of building up a fast emotional tempo, as the Russians have demonstrated in *Potemkin*, *Ten Days*, and other films. If, on the other hand, the tempo desired is a slow, peaceful one, the scenes should run their maximum footage, with as little intercutting as possible. There is one important canon to be observed in all cutting: a photographically dark scene should never be placed next to a light one, except in the rare cases when the contrast is deliberately planned to heighten some dramatic effect, as, for example, a cut from a scene showing the hero's squalid surrounding in the slums to a scene of the heroine's bright boudoir on Park Avenue. In this case the contrast between the low-key photography of the first scene and the high-key photography of the second heightens the emotional contrast of the two settings. Incidentally, if it were desired to establish the fact that the poor hero were in a happier *milieu* than the wealthy heroine, the photographic contrasts could be reversed, and be equally powerful aids in building to the desired emotional response.

Now, editing is a twofold remedy. It will give a long, useful life to new films, and rejuvenate old ones. Most of us cannot help remarking, when we view our older films, on the improvements we could make in them with our present knowledge. We can't often rephotograph them, but we can always re-edit them, and if we do this carefully, we can often make our old, tiresome films seem surprisingly new. This also applies to commercial library films we may have bought. But as these have usually been edited by experts, we should guard against over-refining them, lest the cure be worse than the disease. However, in the case of travel films, it is always a wonderful livener to cut in intimate shots of our own making with films of places we've been.

Another aid to both editing and re-editing is the possession of a good assortment of "stock shots." All studios maintain large stock libraries, and in addition often find it necessary to purchase additional scenes from the several commercial stock libraries in existence. Therefore, in cutting the amateur picture, no scenes of even passable photographic quality should be thrown away; instead they should be carefully saved and catalogued for future reference. Furthermore, the amateur should at all times be on the lookout for interesting scenes to add to his stock library. Very often one will come upon some unexpected bit of action while filming something else. Don't be afraid to use a few feet of film on such bits, for there is no telling how useful they may be in the future. This applies to even the most ordinary scenes encountered while travelling, for such scenes can, with the aid of a little ingenious cutting, give the impression that the whole action of the picture was photographed around the location of the "stock shot," instead of at home, where it really was made. The studios make use of this expedient in many films apparently laid in foreign locales. An outstanding example of this is *The Four Feathers*, in which scenes actually made in the Sudan were so cleverly cut into the intimate action scenes made in the Hollywood studio that the audiences were cajoled into feeling that the whole thing was made in the Sudan. Careful study of such professional pictures will soon show the immense value of individual stock libraries.

Another point akin to editing is the use of color. Nothing can add more charm and newness to a picture than the judicious use of the various methods of coloring monochrome pictures. There are two processes: *Tinting* and *Toning*. Tinting is the more common, and consists of coloring the film-base, which makes the projected picture delicately colored in the highlights and half-tones, but with deep, black shadows. Toning, on the other hand, means coloring the emulsion on the film, but leaving the celluloid base clear. This gives a picture in which the blacks, and shadows are a fairly deep color, the various greys are lighter shades of the same color, but the whites and highlights, where there is no silver deposit, are pure white. Of late, most laboratories have gotten out of the habit of doing much tinting and toning, but there are still some where it can be done. Users of reversal stock will have to have both operations done to their original film, naturally, but the users of the negative-positive system can have their prints made on stock which is already coated on a colored base. The tints commercially available on 16 mm. positive stock are straw, amber, blue, green, flame, and violet. The only tones commercially available in this country are blue and sepia. There are also several devices made for interposing colored discs between the projector and the screen, which gives an effect similar to tinting: a similar pseudo-toned effect can be worked with colored footlights shining on the screen.

A few of the uses of tones and tints may be suggested here, but the real range of their uses is almost inexhaustible. Some of the more obvious ones, however, are sepia *tones* for hunting scenes, blue *tones* for snow-scenes, clouds, and some marines; blue *tints* for marines where water and sky predominate, and are photographically light; the same blue *tint* for night scenes; amber *tint* for artificially lighted interiors, and either that or straw for scenes where the warm, golden glow of the sunlight figures strongly; green *tint* for landscapes; and flame-color for fire scenes, and those illuminated by flares and campfires. Combinations of tones and tints are often remarkably close approaches to natural color. For instance, forest scenes, hunting scenes, and wild-life subjects are made tremendously realistic by the use of a green *tint* and a sepia *tone;* while marine sunsets gain new beauty when made in a blue *tone* on either pink or flame *tinted* stock. In fact, almost everything can be improved by the intelligent use of tones and tints. A shining example of this is the *Pathé Review,* which, edited by Terry Ramsaye, is made through the use of these processes, one of the most consistently beautiful short subjects now being regularly issued. For those amateurs who have the inclination to make their own tones and tints, either on positive or on reversal stock, there are provided in the appendix of this book a great variety of formulae, many of which, though their component materials are obtainable from several sources in this country, are not practiced by the commerical laboratories: yet they are not difficult to use, and they will give an endless variety of colors. To the experimentally inclined, there is no field more interesting nor productive than this one of toning and tinting.

VI.

Titles.

Before a film is complete, it must have titles. Many amateurs are prone to let this important detail slip merely from lack of confidence in their abilities to write or photograph the proper titles. This is a serious mistake, for the lack of titles detracts tremendously from the quality of their pictures. If one can extemporize verbal titles while he is projecting his film, he can certainly find time to condense these "titles" into written words, and thereafter let the picture speak for itself, which it will do far more effectively than he can.

The principal reasons for using titles are:

1. To explain the theme and purpose of the picture.

2. To identify and characterize the actors, the settings, and the time of the action.

3. To convey ideas which the pictorial actions cannot or do not convey; as, spoken dialog.

4. To cover lapses of time, changes of location, or jumps in continuity.

5. To economize in the matter of footage, and to save production expense, where substituting for scenes not shown.

In some of these cases, titles can sometimes be dispensed with; in others, they cannot. It is obvious that pictured action is always more effective than the printed word. Therefore, especially in making films which can be shot from some sort of premeditated scenario or outline, never include a title in the script where some visual device can be used. Such pictorial devices are always more telling than even the best titles, and give subtlety to a picture. The use of such things—unhappily now a declining art, since the coming of sound—has been one of the most important artifices of the great directors of the Lubitsch-Chaplin school. In any event, use titles sparingly: when in doubt about a title—don't use it!

But where titles are used, be sure that they are perfect. One need only see a few of the early films to realize the tremendous harm badly written titles are capable of. Even in the most gripping moments, the exaggerated heroics, the trashy sentiment, and the pedantic explanations offered by these titular monstrosities are now mirth-provoking. A parallel might be found in the vogue of *After Dark* and other antiquated melodramas on the stage today—as comedies. At any rate, be careful that your titles are so worded as to be in perfect harmony with the mood of your picture, and for heaven's sake, don't overwrite. Make them clear and concise; brief, but not telegraphic. Don't be afraid to re-write even the simplest caption a dozen times or more, until you feel that it cannot be improved. Keep the wording clear, correct, and understandable, without unnecessary slang or technical terminology. Dialect titles are hard to write, and harder still to read, so avoid them. Likewise, be careful in your wise-cracking. Remember that humor is one of the fastest-changing parts of modern life: nobody reads yesterday's funny-papers, nor will you laugh at last year's smart-cracking titles. Let the action carry the humor wherever possible (this is *not* an argument in favor of slapstick and custard-pies!), and, when comic titles are needed, remember that for every George

Marion, Jr., and Ralph Spence we have, we have had to suffer the work of a dozen inexpert punsters. If your picture is flat, badly written wise-cracks on the title-cards won't help it.

A point to remember in connection with titles indicating a change in time or place is that the length of the title should be somewhat proportional to the time or space gap that it bridges. Action occurring say a few hours or a few days later can be introduced by a title bearing just those words; but if several years elapse, a title bearing just that bald statement is often on the screen for too brief an interval to let the audience readjust itself. In such a case, in order to avoid becoming too wordy, it is a good plan to fade, or iris, out on the preceding scene and into the succeeding one; if the lapse of time is practicularly long, the title may even be faded in and out, too. It is, by the way, always a good policy to fade in and out of scenes connected with such changes of time or place, except, of course, where direct cuts between separate locales are made to maintain parallel action.

Concerning the footage to be allowed for titles, the practice generally followed by professionals is to allow one second per word for the first ten words, and thereafter one-half second per word. For 16 mm. use of the same standard may be employed, but as professional titles are timed for the reading-speed of the *average* intelligence of the general public, while the home movie is usually presented before audiences of a much higher level of culture, a standard of one-half second per word—with a minimum of three or four seconds—may safely be used. In the Pathex 9.5 mm. system, the titles are made on only two or three frames, and are automatically held stationary in the projector by notches on the *second* preceding frame. Thus a single frame is sufficient for most titles: but if more time is needed, the title is made a couple of frames longer, and two successive frames are notched. *Never, though, notch alternate frames, for this will stop one of the notched frames on the screen.*

The titles themselves, regardless of what system is used to project them, have in some way to be photographed on the film which is to be included in the picture. Normally, the words are lettered on cards which are subsequently photographed with a movie camera —9, 16, or 35 mm.—like any other subject, but since the rise of amateur pictures, there have arisen many other devices made for amateurs who do not feel expert enough to do this lettering by hand. Some of these devices make use of celluloid letters which fit into slits on a black, felt-covered board— others make use of cut-out metal letters which adhere to a magnetic board; still others use cut-out wooden blocks; but the principle involved is the same as that with the conventional cards.

The simplest sort of title is the plain, printed card, carrying the letters, and no more. This card may be photographed so as to show up white, with black letters, or the customary black, with white letters. The latter is generally preferable. For most purposes this is best done by using a white card with black letters, and

Notching Pathex Titles. The notched frame shown will stop the projector on the second following frame.

photographing it on positive film. Negative film could, of course, be used the same way, but positive stock gives a sharper contrast between the black and white, and costs less. Reversal film, of course, would not do at all, unless the card itself is black, with white letters. If one wants a negative of the title, the card should also be black, but positive stock still used in the camera.

For the more important titles, and wherever quality is of greater importance than cost, hand-lettered titles should be used, for hand-work gives a distinctive quality that printing cannot achieve. This hand-work may be done by the amateur, if he feels competent to do it, or by any of the many titling firms throughout the country. The title-cards can be of small size, but it is safest to use larger ones —say from 11x14 inches up—as not only are minor errors in execution less noticeable, but the camera need not be brought so inconveniently close when photographing the card. In the actual photographing, camera and card must be parallel in all planes, and the optical axis of the lens perpendicular to the centre of the card. A handy way to assure this is to point the camera downward, above the card, and drop a plumb-line from the centre of the lens to the centre of the card. The card must in any case have absolutely even illumination. It need not be unusually powerful, as titles are usually made at a reduced speed, but the light it does get must be absolutely even, or one side of the title will seem more brilliant than the other. Of course, the more powerful the illumination, the better, for a smaller diaphragm opening may be used. The exposure may be determined by making and developing test strips, if one does his own developing, or, otherwise, by such an exposure meter as the reliable *Cinephot.*

In case that something more than the mere wording is desired, there are many ways of decorating titles. One of them is the use of mottled or patterned backgrounds. The titles can be lettered on any material, naturally, and there is a vast selection available. Wall-paper is often convenient for this purpose, but it must be remembered that the photographic value of the pattern may be far

A photograph makes a pleasing background for a main title.

different from the visual value; as a safeguard, use your monotone glass to inspect it before you shoot.

Another very popular method is the use of a specially printed still picture for a packground. Almost any picture suiting the theme of the film can be used. If a special photograph is made, the negative is correctly exposed, but slightly underdeveloped, while the print—usually an enlargement—is rather overprinted, so as to give a good, dark print, of good gradation, but limited scale, with no tones above a middle grey, so that the pure white letters stand out well. A buff stock for the print helps to make it seem soft, and to bring out the white letters. A variation of this would be to letter on a sheet of clear celluloid—not too thick a one—and superimpose this on the photograph when photographing the title, thus preserving the background print for future use. A further variation is to make an enlargement from the first frame of the succeeding scene, using this for a background. When the title is completed, the cut from the title to the action is almost imperceptible, the title disappearing and the background coming to life. Still another variation is the use of such a device as the well-known Heintz or Goertz title-hoods, in which the lettering can be made on a transparent support: in this case, use a tripod, and first make a long-shot of the background desired, then—with the camera running—shift the focus until the lettering is in focus, refocussing on the scene when the title has had enough footage.

Such art-titles should only be used at the beginning and end of a picture, and at points in the action where there are important changes in time, place, or dramatic mood. For other titles, simplicity should be the keynote. A dignified border is sometimes desirable, particularly one bearing the name or initials of the filmer, as was the style in professional films a few years ago. D. W. Griffith's distinctive style is memorable, as he always had either his signature or initials worked into the border of every title. Such a border might be made up as a cut-out, or on celluloid, to be used in all the titles in a picture or series of pictures. Another "stock" title is, of course, *The End,* which is used in every picture. It is not a bad idea to make up a hundred feet or so of this at a time, using strips cut from the roll as they are needed. It is even better to make a negative of it, to save re-photographing the title-card whenever a new supply of "ends" is needed. Similarly, another stock title should be one identifying the picture as the product or property of the individual. It may carry some such phrase as: *A John Smith Production,* or: *From the Library of John Smith.* Behind may be any sort of background or conventional design desired, such as, for instance, Marshall Neilan's famous *Swastika* trade-mark, Paramount's mountain-top, or, if one legitimately owns such a thing, a coat of arms.

There is such a vast range of possibilities in trick titles that even to suggest a few would fill a complete volume. For instance, there is the whole vast field of animation. Animated titles may range from the simplest form—cut-out letters dancing into the picture and forming themselves into words—up through the more complicated effects of moving, whirling, and exploding circles, stars, and geometrical figures, to the final intricate effects of animated miniatures. These last, such as clouds, dust, smoke, or snow blowing into the form of the letters wanted, can most easily be done in reverse, first photographing the completed title, and then proceeding to disintegrate it into the form desired for a beginning; photographing it, of course, with the camera working backwards, or, in the case of motor-driven cameras, inverted. A still further development of this leads into the fascinating realm of multiple exposure and multiple printing. Aside from furnishing highly spectacular effects, these processes can be very enjoyable to the experimentally inclined camerist. Both are increasingly difficult, and decidedly not to be undertaken by the novice, but there are few thrills that compare with the wonderful sensation of seeing your first successful trick scene or title flash on the screen. This is particularly true of double exposure, where the thrill of knowing that you've been able to match up your separate exposures so that they are in perfect harmony photographically, and in perfect register, is like nothing else in the world.

Once the titles are made, however, there is still much to be accomplished in fitting them into exactly the right spots in the picture. A good title in the wrong place is worse than no title at all. Therefore, before ever you write a line, be familiar with the picture from every angle—especially that of the audience, which is not familiar with it at all. Make sure of each spot for a title: make yourself certain that there is a definite need for a title there, and that a title will not be confusing in that particular position. Then write and photograph your title. After you've assembled your film and inserted your titles, project it a few times for yourself, checking each point carefully. Are the titles worded properly? Are they optically satisfactory: are the words spaced so as to be easily readable? Is the decoration not obstrusive? Does the photographic tone properly match the scenes adjoining? Then, again insure yourself that the title is in its right spot: is it surely not intrusive? Is it, in spoken titles, absolutely clear who is speaking? In this latter case, always avoid cutting a spoken title into a long- or medium shot unless the situation or wording makes the speaker unmistakeable. It is always best to flash a bit of a close-up before and after a spoken title, and then return to the original longer shot. But, above all things, don't let your titles, spoken or otherwise, interrupt the dramatic action. A title, no matter how good, cut into a fast-moving scene, such as the traditional fight between the hero and the heavy, is ruinous to the tempo of the sequence. Imagine giving *Sidney Carton* a title just as the guillotine is falling!

VII.

Projection.

The ultimate goal of cinematography is projection before an audience. We may enjoy making and preparing our films, but above all we enjoy showing them to our friends. Therefore, though in the strictest sense projection is not a part of cinematography, no discussion of the subject, however brief, is complete without some reference to it.

The actual operation of projecting a picture is precisely the reverse of taking it. In taking, the light reflected from an object is collected by a lens, which forms an image on the film; in projection, a light-source behind the film projects an image of the picture through a lens onto a screen, from which it is reflected into the eyes of the beholders. The projecting-machine is essentially the camera mechanism, reversed, and provided with its own light-source. The projector, then, has provision made for holding and moving the film much as the camera does, except that the film, no longer sensitive, need not be shielded from the light, and that in order to give a conveniently long "show," most projectors hold enough film to run for ten minutes or more (1000 ft., 35 mm.; or, 400 ft., 16 mm. or 9.5 mm.). The projector uses much the same sort of lens that the camera does, though it need not be equipped with a diaphragm, as it must at all times work at its widest aperture. The shutter is much the same, but usually equipped with two or three blades, instead of the camera-shutter's one, as the increased frequency of the dark and light periods eliminate the flicker which used to make the movies so objectionable. The shutter may be placed either between the lens and the screen, between the lens and the film, or between the light and the film. Each placement has its advantages, but the latter has the great advantage of cutting off the heat from the film as well as the light from the screen, and is therefore safer and easier on the film. In addition, most amateur projectors have a special "safety-shutter" which drops between the film and the lamp whenever the film stops, or slows below a safe speed. This safety shutter is either of "gold glass" or in the form of a fine grill, so that most of the light will still pass through, but most of the heat will be retarded. This allows stopping the film to show single frames as still pictures, like lantern-slides.

Two things determine the size of the projected picture: the "throw," or the distance between the projector and the screen, and the focal length of the projection lens. If we consider the beam of light thrown by the projector as a pyramid, with its point in the lens, and its base the screen, it is obvious that the greater the separation of the base and the apex, the angles being constant, the larger area the base will cover. Therefore, the longer the throw, the larger the picture. Similarly, if we consider the beam of light from the film to the lens as forming a smaller pyramid, with its angles equal to the corresponding ones in the larger one, and with their apexes meeting in the centre of the lens, it is clear that if we increase the focal length of the lens we will be increasing the height of the smaller pyramid, and, as the film-area forming its base remains the same, its angles must be made smaller: this will have the same effect on the larger pyramid, and, if the same throw is maintained, will result in a smaller picture. Thus, the greater the focal length, the smaller the projected picture.

Now, the size of the picture has an amazing influence on the brilliance of the image, for the brilliancy varies inversely as the square of the area. Thus a screen two feet long does not receive *half* the illumination a screen one foot long would, but *one-quarter* as much. Therefore, though most amateur projectors will cover a fairly large-sized screen satisfactorily, they will give better results if used on screens considerably smaller than their maxima.

The surface of a screen also has a great deal to do with the quality of the picture. Too many amateurs make the mistake of getting a good camera and projector, and then using anything—a sheet, or a white wall—for a screen. This is a great mistake. *We do not see the actual light thrown on the screen: we only see what part of it the screen reflects back to us.* Therefore, if we want to see our pictures at their best, we must naturally use a screen that reflects the maximum percentage of the light that falls on it. Unfortunately there has as yet been no material made that is a total reflector, but some of the best screens will reflect nearly 90% of the light that falls upon them.

There are three classes of screens: the first is the metal or metallized screen. This has the highest reflective power. It may be either of frosted metal, or a non-metallic support treated with a metallic paint of either silver or aluminum. This has the highest reflective power, but gives a picture with a somewhat cold tone.

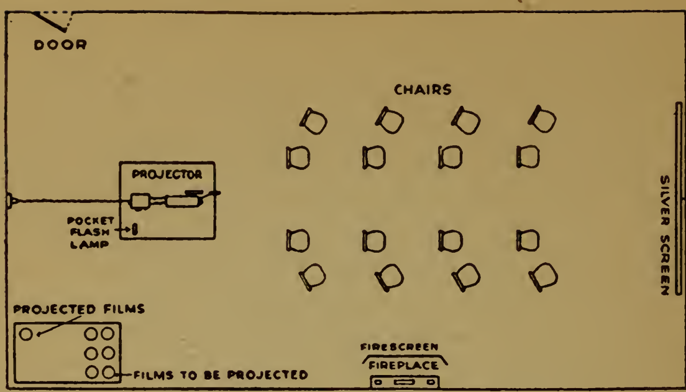
Next is the bead screen: this has a surface covered with tiny, white glass beads. Its reflective power is almost equal to that of the silver-screen, but it gives warmer, more pleasing tones.

Lastly, there is the ordinary, white screen. This can still have a very high reflective power, though not so high as the silvered surface. It gives perhaps the most pleasing tone, and also does not give the heavy shadows seen on the other types when there are waves or wrinkles in its surface.

A screen should always be as opaque as possible, and bordered with a dead, non-reflective, matte black border, as this makes any slight unsteadiness in the projected picture less evident. Furthermore, it should always be remembered that the color of the screen itself governs the highest tone obtainable in the pictures projected on it. If the screen surface were black, no higher tone could be seen; if it were a middle grey, no whites would be visible in the highlights; and, the clearer its white, the better the tone obtainable in the highlights.

The next consideration is the projection-room. If the amateur is fortunate, he may have some sort of a room in his home that he can set aside for an amateur theatre; but if he is like most of us, he will probably have to make the living-room do additional duty. In such a case it is usually wise to get one of the many screens available which are provided with a stand of some sort. As for the projector, it may be set upon the table, or fastened, by means of a special base, upon the same tripod used for the camera. Several different models of projector-stands are also available, and more than a few manufacturers are devising de-luxe table-cabinets for their machines. In any case, the projector should be mounted on a good, firm support. Never, by the way, use a card-table for the purpose: it is too light, and will vibrate with the vibration of the projector, which results in an unsteady picture on the screen.

In arranging a room for projection, the projector should be at one end, preferably on a table or stand large enough to accommodate the various reels to be shown, and the screen placed at the other end of the room. Between the two, the audience should be seated, as close to the centre-line of the projection as is possible, but leaving a lane through which, or over which, the projector throws its beam. It is also advantageous not to have the audience any closer to the screen than is necessary, for the rather considerable enlargement of the tiny frames makes the individual silver grains unpleasantly noticeable on close approach. The projectionist should be in a position to control the lighting of the room. It is not by any means necessary that all the lights should be out during the pro-



An excellent layout for the amateur theatre.

jection; in fact, it is really advisable to have some dim light by which the audience can see a little, and move around, if necessary. A bridge-lamp, with a good, deep, opaque shade, and a small bulb, is excellent for the purpose. This light makes the audience feel more comfortable than the cold, inhospitable darkness, and also lessens the sudden contrast when the film runs out of the projector, and the screen goes brilliantly white. Of course, a good projectionist will stop his machine before this happens—but it takes time to acquire such judgment and skill. The projectionist should also have a small flashlight handy, so that he can see whenever trouble occurs, without turning on the "house lights." It is as well to remember that theatre projectionists work at all times in fully lit booths, and can constantly watch their machines. An amateur can't do this, but a 39-cent flashlight will help him keep an eye on it without disturbing the audience. But, in the dark, an ear is always better than an eye, so train yourself to listen for changes in the even sound of the projector.

The exact arrangement of a programme should be governed largely by the taste of the individual and the audience. No programme should last over two hours, with a short intermission midway. The best banquet is the one from which we get up just a little bit hungry, and so, too, the best film programme is the one which the audience leaves wanting just a little bit more. Once you have an audience in a receptive state of mind toward your efforts, don't wear out your welcome. If your programme is made up entirely either of your own or of library films, there is but little choice as to the arrangement, for in that case the programme will be of one standard, photographically and artistically. If, however, you combine the two, always put your own films *first*, so that they are seen before the audience has adjusted its mind to the professional standard of the library film. Amateur film standards need not fall below professional standards, but as a general rule they do: this is not to the discredit of the amateur, for the professional cinematographer, director, or editor is a man with many years' experience in his individual field of work—a trained specialist, in the most specialized industry in the world. Given the proper amount of experience, the proper mastery of technique, and, above all, the proper, painstaking frame of mind, the amateur *cinéaste* can produce work worthy of ranking with the best. He can, in some ways, even excel the professional, for he is not bound by the ties of commercial production. He is not bound to a myriad-minded, international audience, nor is he hurried by ironclad time schedules. He has the time, and if he wishes it, the opportunity to experiment for the exact, the perfect cinematic effect. And in this age of vocal pictures, it is to the amateur that we must look for the preservation of the true art of the silent screen.

The Original 16mm. Camera: the Model A Cine-Kodak.

CINEMACHINERY FOR THE PERSONAL MOVIE

Cameras

THE amateur movie enthusiast of a few years ago had small choice when he came to purchase equipment for his film work. Almost without exception, cameras and projectors were designed with only professional use in view. Apparatus primarily intended for serious amateur use hardly existed; and what little there was offered so few inducements in the way of reduced bulk and minimized expense that the average amateur found himself driven to the use of professional or semi-professional apparatus, no matter how unsuited he found it to his needs.

Today an entirely different state of affairs exists. There are now two absolutely distinct and separate classes of cinemachinery: professional, and amateur. Strangely, they are not competitive, as the early manufacturers feared that they might be, but complementary, for the mere existence of each is indirectly of aid to the other.

It is hardly necessary to go into the details of the purely professional cameras here. They are designed exclusively for studio and industrial use, and this, together with their considerable bulk and cost, both initially, and in operation, puts them definitely out of the field of interest of the individual user. Even if the amateur is one fortunate enough to be able to ignore expense entirely, one cannot advise him to purchase a professional outfit any more than one could advise him to purchase Major Seagrave's 250 m.p.h. *Golden Arrow* for a pleasure car. Both are highly specialized machines, ideally adapted to their designated purposes, but entirely unsuitable for personal use. The best verification of this lies in the fact that the majority of professional cinematographers, though they may have as much as $10,000 invested in their Bell & Howell, Mitchell, or Fearless outfits, prefer to make their personal films on 16-mm. stock with Cine-Kodaks, Filmos, Victors, etc.

Of the once great variety of semi-professional standard cameras, few remain, for, taken as a whole, this type of camera was essentially a makeshift. While many of them were of excellent design and workmanship, and capable of producing fine pictures, they were aiming at two opposite fields: that of the small professional user; and that of the amateur. For the first use, they were often too light, and lacked many necessary refinements; while for the second, they were almost always too heavy, too bulky, and too complicated. Of course, there are still amateurs who look longingly at these cameras, considering the possibilities that they hold forth of paying for themselves in semi-professional use: but the coming of sound pictures has narrowed down the possibilities of such profits tremendously, while, at the same time, the industrial field has turned largely to the 16-mm. standard. Therefore, one cannot help advising the prospective purchaser to start at once in the latter film, for, not only is there as great an opportunity for profit, but the apparatus is better suited to individual use, more quickly mastered, and far less costly to keep up while it is being mastered.

There are today two distinct amateur standards. One of these uses a film 9.5 mm. wide, and the other a film 16 mm. wide. Both were introduced at the same time: but today the 16-mm. standard is unquestionably the most popular, although the 9-mm. is used a great deal abroad. The cameras intended for use with either of these systems have been designed to eliminate every preventable fault. For instance, the majority of them will not close unless they are properly threaded, nor will the turret-equipped models run unless the lens is properly centered for photographing. In many models fitted with super-speed or half-speed attachments, these attachments cannot be used accidentally, as the release lever must be specially turned and held in place while running at high speeds. Tables indicating the correct exposure under most conditions are placed on the cameras, so that there is little chance for error in this important factor. The short-focus lenses used have great depth, so that focussing, too, is simplified as much as possible. In a word, the camera is designed to think for itself, almost.

The first 16mm. camera to be introduced was the Model A Cine-Kodak. This camera was, and still is, undoubtedly one of the finest cameras ever made for amateur movie work. Furthermore, it is the camera par excellence for scientific work of all kinds. As it was designed before the idea of a motor-driven camera had become accepted, it is naturally a hand-cranked model, and considerably more bulky, though little heavier, than the later models; therefore, though primarily intended for hand drive and a tripod, it can be held in the hand when fitted with the auxiliary electric motor-drive made for it. But, for the particular field to which this camera is best adapted, the fact that it is hand-cranked is not a defect, but a definite advantage, for it allows almost professional control of the speed of taking, which, aside from its uses in scientific cinematography, allows, in amateur dramatic filming, a considerable control of the speed and tempo of the scenes presented on the screen. Furthermore, through auxiliary gearboxes which screw onto the side of the camera, a considerable range of superspeed (slow-motion) and slow-speed effects are possible, while animated cartoons and figures can easily be filmed with the one-frame-per-turn movement provided. The camera itself is contained in a sturdy aluminum box, 4⅝x8x8⅝ inches in size, and holds the usual 100-ft. rolls of 16-mm. film. The lens normally fitted is an F:1.9 Kodak Anastigmat, mounted so as to be easily interchangeable with almost any other the user may require. The finder is of the direct type, through a tube opening at the rear of the camera, while a reflecting finder is also supplied. Both the focus and the film footage are indicated by dials at the rear of the camera.

The same firm later announced their Model B Cine-Kodak, which, as it was exclusively a hand-camera, and designed to appeal more directly to the average amateur, by virtue of its simplicity and precision, has become one of the most universally popular of cine outfits. It is a neat, compact box-form camera, covered with leather, which may be either black, gray, or brown. In size it is approximately the same as a postcard-size still camera, 9⅝ x3-1/16x5-9/16 inches, and weighing five pounds, loaded. It is daylight loading, with a capacity of 100 feet of 16mm. film, which is enough to record action for a screen time of over four minutes. It is driven by a

The Model B Cine-Kodak, with F:1.9 lens equipment.

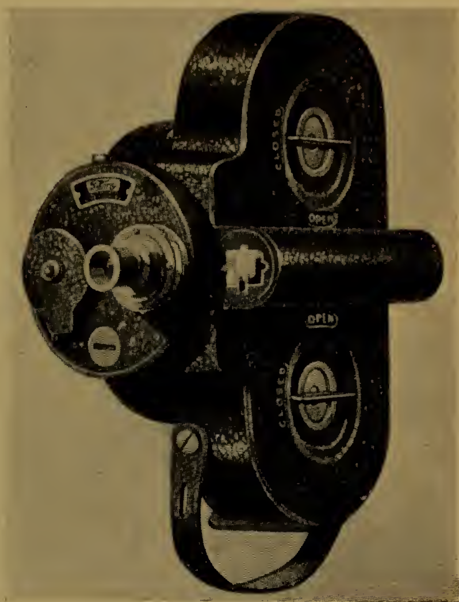
powerful spring motor, which will expose twenty feet of film at each winding. The lens equipment on the original model was a fixed-focus F:3.5 anastigmat, equipped with a supplementary "portrait attachment" for closeups. The more recent models have been equipped with an F:1.9 lens, particularly suited to *Kodacolor* use, in a focussing mount; the F:3.5 model is still available, however. The faster lens is removable, and may be replaced by a 3-inch telephoto lens, working at F:4.5, which will give an image three diameters larger. Two finders are provided, one a reflecting finder, familiar to all users of still cameras, and the other, the handier "sight-finder" (sometimes called an *Iconograph* finder), for use at eye level. Only the latter, or rather, a supplementary one of the latter type, can be used with the long-focus lens. The footage-indicator is at the top of the case, and is particularly accurate, as it can be adjusted to each roll of film. The F:1.9 Model B Cine-Kodak has the distinction of being the original Kodacolor outfit.

The latest addition to the Eastman line is the Model BB Cine-Kodak, which is virtually a smaller edition of the Model B. It is

The Model BB Cine-Kodak, with F:1.9 lens.

quite a bit smaller than its predecessor, measuring 8⅜x2-7/16x 4-11/16 inches, and weighing only 3½ pounds. It is available in the same finishes as the other, and also in blue. Its capacity is but 50 feet of film, and the smaller motor will drive only ten feet of film at a winding: however, few scenes will ever exceed five feet in length, so this is more than ample. The Model BB has the added advantage of having a half-speed action as well as the standard speed. This allows a considerably greater exposure, making many scenes in unfavorable lights possible. The lens-equipments are identical with those of the Model B, as are the footage-meters, finders, etc. In both models, space is conserved by placing the film rolls side by side, with an ingenious and simple loop-and-roller arrangement for bringing the film from the inner (feed) roll into the plane of the lens.

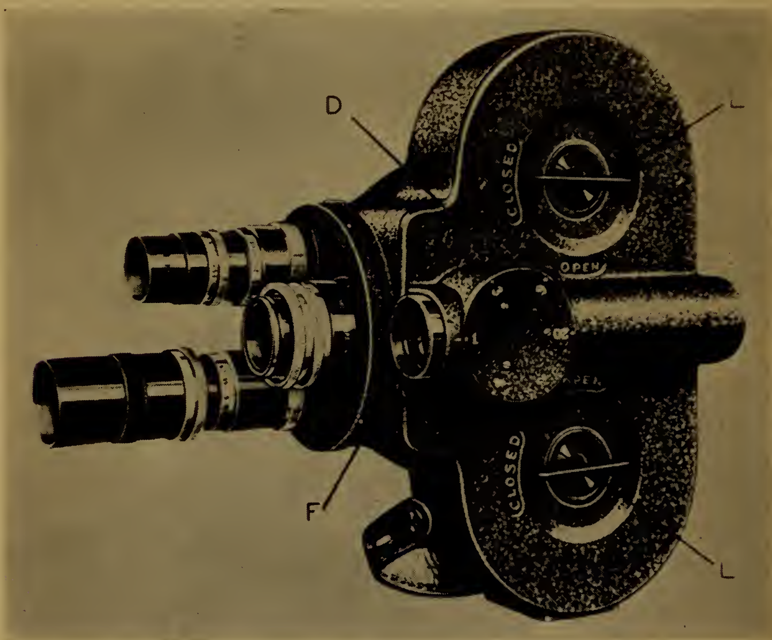
At the same time that the Eastman Company introduced their first Cine-Kodak, the Bell & Howell Company, long one of the foremost makers of professional cinemachinery, introduced their first amateur camera, the famous *Filmo,* for 16-mm. film. This was the first of true cine hand-cameras. It is designed so that the case of the camera conforms as closely as possible to the actual outlines of the mechanism within, and has been so widely imitated that the most frequent descriptions of different camera shapes are either as



The Bell & Howell FILMO.

"box-form" or "Filmo-shaped". The size is approximately 5½ x 8x4⅝ inches, without lenses, and the weight is 4½ pounds. The finish is black, crystallized-finish enamel. Two models are offered, the series 70 and 75; the former is in turn offered in four distinct types, known as the 70-A, 70-B, 70-C, and 70-D.

The Filmo 70, the basic type, is a compact, motor-driven camera with a capacity of 100 ft. of 16-mm. film; it will expose 20 to 30 feet of a winding. The lens equipment can be varied to suit any individual need, as all lenses are interchangeable instantly, and those offered range in speed from F:3.5 (and F:4.5 and F:5.5, in the telephotos), to F:1.8 for Kodacolor, and now to the extreme of F:0.99; while any focal length from 20-mm. to 6 inches can be obtained. The finder is a unique, spy-glass type, mounded beside the lens, on the door of the camera. Lines may be etched on the front lens of the finder to indicate the fields of various lenses, or supplementary masks can be used. In the new 70-D model a very ingenious self-masking finder is used, which, by the rotation of a dial, automatically masks the field to correspond with that of any given lens. In the matter of speeds, an almost infinite variety are available: the 70-A has two instantly changeable speeds—either 8 and 16 frames per second, or 16 and 32 per second; the 70-B is a special superspeed model working at the fixed speed of 128 frames per second (eight times normal, for slow-motion scenes); while the new 70-D has available seven speeds—8, 12, 16, 24, 32, 48 or 64 frames per second, any of which is instantly available by merely turning a dial on the side of the camera. In addition to

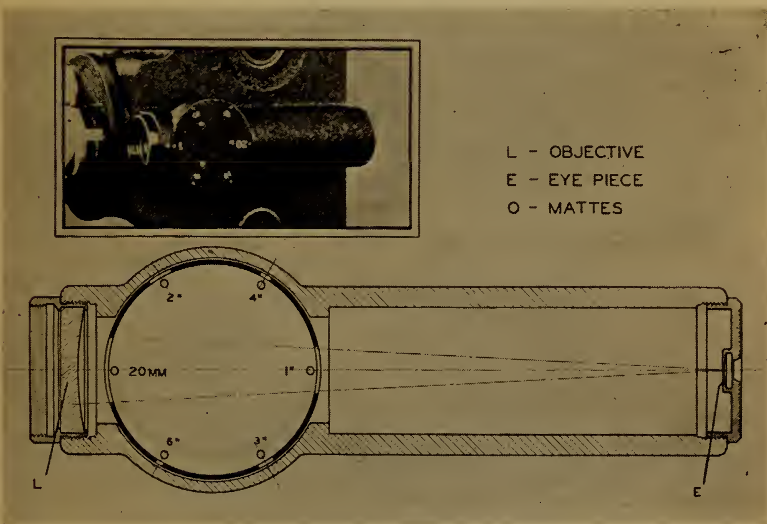


The latest FILMO, Model 70-D. L. L. camera-cover locks; F, lens of finder; D, dial controlling finder masks.

this, the 70-D has an integral turret-head upon which any three lenses can be mounted, and which permits instant change from one lens to another. Decidedly, it is one of the most advanced and flexible amateur cameras on the market.

The *Filmo 75* is another innovation in camera design. It is probably the smallest camera made which retains a capacity of 100 ft., for it measures only 1⅝ x 4 x 8¾ inches overall. Although it is regularly equipped with an F:3.5 fixed-focus lens, it may be had with any lens desired, including Kodacolor equipment. Of course it is daylight loading, and motor-driven, exposing 20 ft. per wind. The movement provides only for the standard 16 frames per second. Despite its amazingly small size, it is an excellent photographic mechanism, a true pocket-cine.

The third of the original trio of 16-mm. cameras is the *Victor*, which is the design of Dr. A. F. Victor, one of the pioneers of cine engineering, and the designer of what is probably the earliest American amateur cameras—a 24-mm. outfit introduced many years ago. The first Victor 16-mm. camera was a small, hand-cranked box-form camera of the very simplest construction, yet capable of excellent work within its somewhat limited range. This was soon superseded by the more advanced Victor Model 3, which is now also supplemented by the lately-announced Model 5, which is of the same design, but embodying improvements which place it among

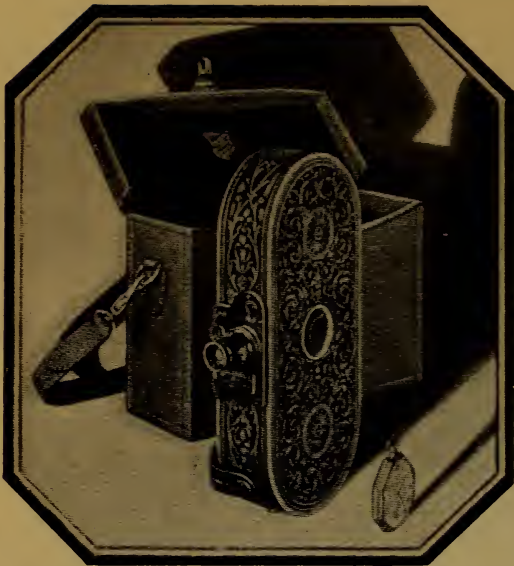


Cut-away view of multiple-masking finder of FILMO 70-D.

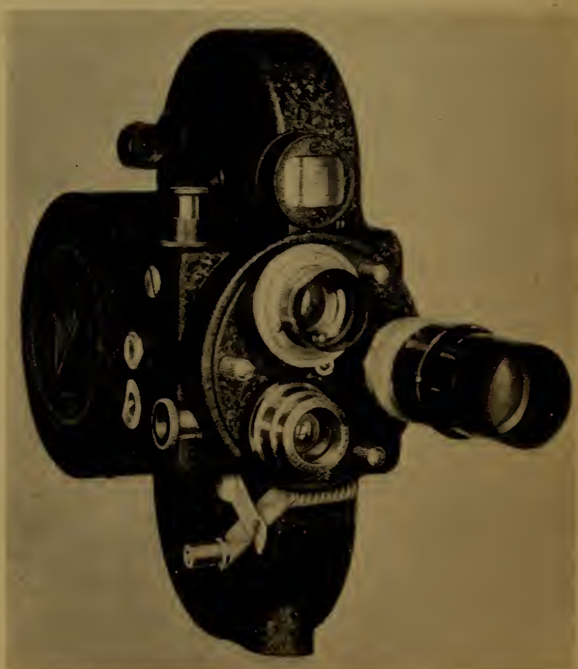
the most flexible amateur cameras in the world.

The Model 3 Victor is of the popular, irregular shape, measuring 3¼ x 8 x 6 inches, and weighing 4¾ pounds. It has a sturdily constructed, die-cast aluminum body, finished in black crystalline enamel. The motor is powerful, and drives 28 feet of film to each winding. Three speeds are available by merely turning the releasing button: 8, 16 or 64 frames per second. In addition, the Victor is the only American amateur camera made which permits either motor drive or hand-cranking—a valuable feature to the advanced worker. The lenses are in standard, interchangeable mounts, allowing any lens to be fitted. There are many detail refinements of much convenience, such as the very simple, self-setting footage meter, and the provision of a level in the finder, which is also arranged so that it is self-compensating for close shots.

The new Model 5 is essentially the same design, but with the addition of a three-lens turret, a greater range of speeds, and, most important of all, a provision for visual focussing of the lenses. The speeds provided in this model are 8, 16, 24, 32 and 72 frames



The Watch-thin FILMO 75



The New Model 5 Victor Camera, with Turret and Visual Focusing Device.

The Victor Cine Camera.

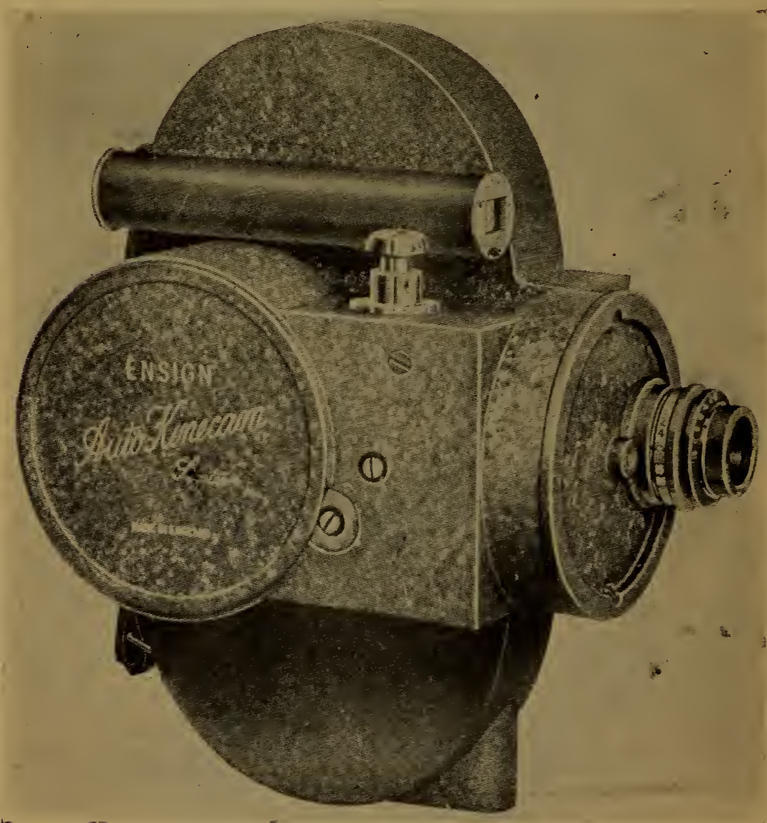
per second, and the operating button may be locked in position on either 8, 16 or 24 frame speeds. The visual focussing is provided by rotating the lens desired through 1/3 turn of the turret, which brings it into place before a ground-glass focussing screen, the image from which is reflected into a magnifying eyepiece by a prism. This enables one to focus on any object with absolute accuracy—a valuable feature in this day of high-speed lenses.

Abroad a strikingly similar design is the British *Ensign* "Auto-Kinecam," although Messrs. Victor inform us that it is definitely *not* a foreign-market version of their product. However, externally it appears almost identical with the Model 3 Victor, although there are marked differences in such details as the type and position of the footage-meter, and the finder, which is of the tubular, spyglass type. It has, however, the same three-speed range, and provision for hand-cranking.

One of the most recent arrivals among 16mm. cameras is the

Cine-Ansco. This is a very attractively finished boxform camera, with a capacity of 100 ft. of film. A unique feature of its design is the fact that it permits a straight feed of the film by the simple expedient of up-ending the box—making what would normally be considered the top serve as the front. The lens-mount is standard, and thus almost any lens may be used; the ones supplied work either at F:3.5 or F:1.5. The finder is of the inbuilt, tubular type, and compensates on close shots by revolving the eyepiece, which is pierced eccentrically. Two speeds only are provided—normal and high-speed, the latter being thrown in by a special button which must be held down while the camera is running at that speed.

One of the most advanced of the foreign cameras to reach this country is the German *Cine-Nizo 16c.* This is another of the



From England: The Ensign "Auto-Kinecam."

irregularly-shaped designs, and is distinctively, almost cubistically shaped. It measures 7½x6x3 inches, and weighs 99 ounces. The motor drive is capable of running off 33 feet of film at a time, and is unique in respect to its speed range, for it may be run at abso-

From Germany: The Cine-Nizo

lutely any speed desired between 8 frames per second and 64 frames per second. In addition, the camera may be hand-cranked, and is the only one made in which this feature may be employed without previously running down the motor. As in professional cameras, two crank-shafts are provided: one geared to eight pictures per turn, for normal use, and the other to a single frame per turn, for titles, animation, and trick scenes. A further unique feature of the Cine-Nizo is the fact that it can be fitted with a reflecting prism arrangement which makes possible critical focusing on the film itself, as in professional cameras. Obviously, this feature, combined with its adaptability to hand-drive, makes it a most desirable equipment for scientific and advanced amateur use.

There are also two other Cine-Nizo models, though neither has appeared in America as yet: the Model F, for 9.5mm. film, and the Model B, for 33 feet of 16mm. film.

The only 33 ft. capacity 16mm. camera as yet introduced here is the remarkable little Zeiss-Ikon *Kinamo S.10*. This is probably the smallest motor-driven 16mm. camera in the world, as it meas-

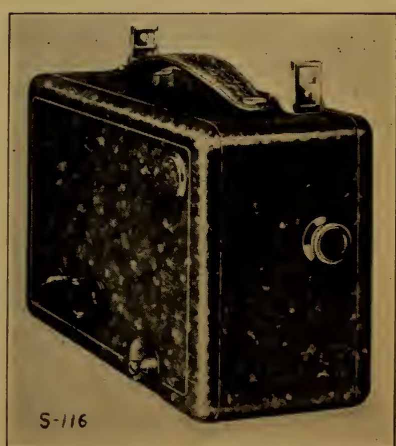
The Cine-Ansco

ures only $4\frac{3}{8}$x$3\frac{1}{2}$x$2\frac{1}{2}$ inches, and weighing slightly over two pounds. The motor will run 13 feet of film at a winding. The lens supplied is a fixed-focus Carl Zeiss Tessar of 15mm. focal length, working at F:2.7. The film is supplied in special double magazines, instead of the usual rolls.

The latest, and most revolutionary development in the 16mm. field is the Kodel *Homovie.* This takes four tiny pictures on the same film area ordinarily devoted to a single picture, by means of a compound movement, which moves the film horizontally as well as vertically. The illustration shows the zig-zag sequence of the pictures as compared to the normal. The camera itself is boxform, and measures $8\frac{1}{2}$x$3\frac{1}{2}$x5 inches; it uses any make of film, taking hundred foot rolls, but impressing on them four times as much action as is usually photographed.

The Smallest 16mm. Camera: The Zeiss-Ikon "Kinamo S-10," and its charger.

How the Kodel HOMOVIE system saves film. RIGHT, film made by Kodel (left) and standard 16mm. cameras (actual size). LEFT, enlarged section of Kodel film, showing sequence of tiny frames, four on the same area ordinarily occupied by one.



The Remarkable Kodel HOMOVIE Camera.

The Pathex Motocamera for 9.5mm. film.

The 9.5mm. standard is represented in America only by the Pathex—the originators of the standard—although abroad there are several other makes, such as the 9.5mm. Nizo already referred to, the *Bolex,* etc. There are two models offered, one motor driven, and the other hand-cranked, though this latter can be fitted with an auxiliary motor-drive. The motor driven model, styled the *Motocamera,* is a compact, boxform model 4¾ inches square by 2½ inches wide, covered in black leather, and weighing three pounds. Its film capacity is 26 feet, which is enclosed in a special double magazine. The motor will drive the full 26 feet at a winding. The lenses regularly supplied are of fixed focus; the choice of lens speeds is between F:3.5 and F:2.7. With the F:3.5 equipment this is probably the least expensive quality, motor-driven camera in the world.

The hand-driven model is one of the most compact of motion picture cameras. It measures 4x3½ x1½ inches. It is equipped only with the F:3.5 lens, and is undoubtedly the cheapest fine movie camera ever made. Instead of the inbuilt tubular finder, it has a direct finder at the top of the case. The motor drive unit which may be added to this camera will expose approximately a third of a roll of film at a winding, though abroad there is available another type of motor unit, called the *Camo*, which will run a full roll (26 feet) at a winding. This model of the camera, when used without a motor, must invariably be used on a tripod. As the lenses are of fixed focus, supplementary lens sets are supplied for use at distances of 1½ feet, 3 feet and 6 feet. Despite the small size and modest cost of these cameras, they are in every way capable of serious work, as is proved by their considerable popularity abroad.

Projectors

MOTION picture projectors for home use have proceeded along the same evolutionary course as have amateur cameras, but various factors combined to speed the evolution of the projector ahead of that of the camera. Therefore, at the time when the 16mm. film system was devised, there were already a fair number of 35mm. projection outfits designed exclusively for home and school use available. Chief among them were the DeVry and Acme "suitcase-type" projectors in America, the DeBrie "cine-cabine" *Jacky*, in France, and various semi-portable stand-projectors like the German Ica *Monopol*. The famous 28mm. *Pathescope*, the first projector designed exclusively for home use, had but lately been discontinued by its makers in anticipation of their forthcoming 9.5mm. *Pathex* system. But despite this rather extensive background, the home projector did not evolve into a truly amateur equipment until after the introduction of the 16mm. system gave the manufacturers really extensive experience with the distinct needs and possibilities of the amateur field.

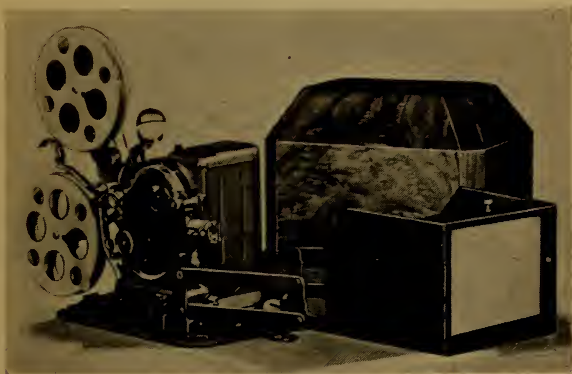
The first 16mm. projector to be introduced was the Model A *Kodascope*, the companion-machine to the Model A *Cine-Kodak*. This is the largest 16mm. projector made, but although later designs have achieved greater compactness and more decorative appearance, none have surpassed it in mechanical efficiency. It is especially suitable for use in schools, clubs, churches, etc., and for the individual user who is more interested in having an accurate, durable machine than a household ornament. It is fitted with a powerful 250-Watt lamp, and will project a larger picture than is usual in 16mm. exhibition. The lens-mount is a single, instantly removable unit, which, for Kodacolor work is replaced by a similar unit which carries the Kodacolor filters permanently affixed. The lenses usually supplied are of 2-inch focal length, which will give a picture 39x52 inches at a distance of 23 feet. A 1-inch lens is available, which will give a picture of the same size at 11½ feet, and a 5-inch lens, giving this same size picture at 57½ feet can also be had. The projector can be equipped to run on any current, from 32 to 250 volts; the lamp voltage is controlled by a rheostat on the machine according to the indications of an ammeter set into the base, where the control switch and speed-controlling rheostat are mounted. The lamphouse is directly behind the film aperture. A gold-glass safety shutter permits the projection of single frames as still pictures, but no reverse movement is supplied. Rewinding is by a geared, hand rewind built into the reel-carrying arm.

The Model B *Kodascope* is the deLuxe member of the *Kodascope* family. It is a small, exquisitely finished instrument designed to

The First 16mm. Projector: the Model A Kodascope.

appeal to the amateur who wants the utmost in convenience and appearance. Undoubtedly the most arresting feature of this model is the fact that it is self-threading. This not only simplifies and expedites operation, but ensures that the machine is correctly threaded every time. The units of the machine have been arranged very compactly, much space being saved by using a reflecting optical system, and placing the lamp house and shutter at the side of the machine instead of at the rear. The lamp is a 250 Watt prefocused bulb like that of the Model A, but it is burned at a lower

Amperage. The machine is adaptable to either direct or alternating current of 90 to 125 volts. The controls—switch, motor-reverse, stop of single-picture projection, etc., are grouped on the right side of the machine, while the rheostats controlling the lamp current and the motor speed are at the left. As in the earlier model, either walnut, ebony-inlaid case, and a translucent screen fitted on folding arms attached to the base of the case, to which also are attached



Home Movies de Luxe: The Library Kodascope, with its cabinet and screen.

1-inch or 2-inch lenses may be used; and Kodacolor pictures may be projected with either. The rewind in this model is motor-driven.

What might be termed a "super-de-Luxe" edition of the Model B Kodascope is known as *The Library Kodascope.* This consists of the above-described projector, in a special bronze finish, in a clips for a spare lens, Kodacolor filters, etc. A special cabinet is also made to serve as a base for the Library Kodascope. It matches the case in design and finish, and the two make a very attractive, as well as useful, piece of furniture for any home. The top of the cabinet, which receives the base of the projector, is a concealed turn-table, so that pictures may be projected in any direction without moving the cabinet. In the cabinet are compartments for twenty-six 400-ft. reels. A shelf, hinged inside the cabinet door, makes a convenient working table. Beneath this shelf is clipped a screen which may be used when the small, translucent screen on the projector is too small for the audience. A deep drawer is provided at the bottom to house a collapsible standard for the screen, and to store the camera and its accessories.

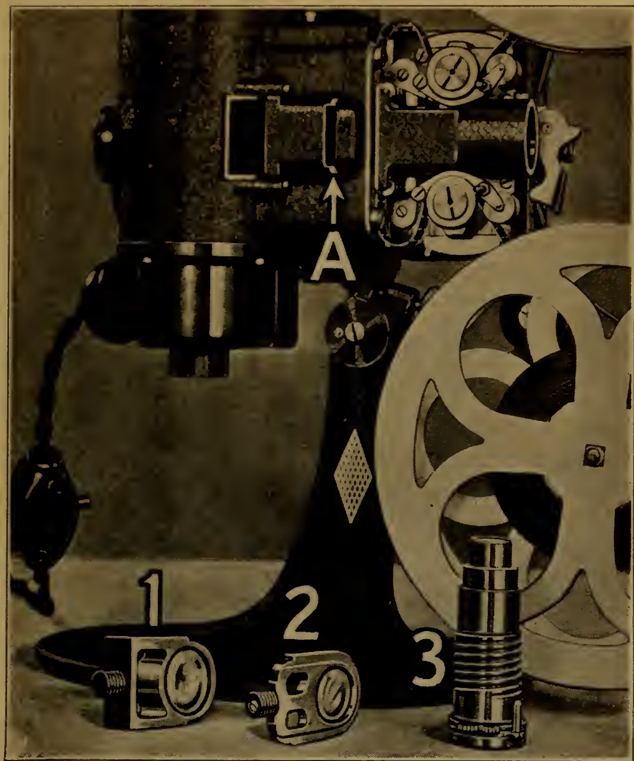
The smallest and least expensive of the Kodascopes is the Model C. This, strangely enough, appeared on the market before its logical predecessor, Model B. It is home projection reduced to its essentials. The units are arranged much the same as those of the

Model B, with the lamp house at the side, instead of behind. The lamp used is a 100-Watt bulb. The machine can be adapted to any current between 32 and 250 volts, and a special 6-Volt model is made for use with an ordinary storage-battery. Either 1-inch or 2-in lenses may be used, but the smaller lamp used limits the effec-

16mm. Movies for Business: the Model C Kodascope with its carrying-case and screen, as supplied for salesmen, etc.

tive picture size to about 30x40 inches. Single frames can be projected, but there is no reverse. The rewind may be either by hand or by motor. A special model of the Kodascope C is supplied with a carrying case at one end of which is built a translucent screen; this is called *The Business Kodascope*, and is intended for use by salesmen, etc. Kodacolor pictures cannot be projected by the Model C *Kodascope*, nor the *Business Kodascope.*

The companion to the Bell & Howell *Filmo* camera is the *Filmo* projector. Its makers have standardized on a single basic design, but produce several models with varying optical and electrical equipment to meet differing needs. The *Filmo* projector stands on a short pedestal rising from a good-sized, oval base. The essential units of the machine are arranged for maximum simplicity of operation. The light is from a lamphouse directly behind the film aperture, with the shutter between the light and the film. The shutter has an opening of 216 degrees, and the film movement is a special 9 to 1 movement which reduces the interval between successive pictures on the screen to 1/160 of a second, reducing flicker even at low speeds. There is the usual safety-shutter for still projection, in this case in the form of a fine metal grill, and in addition a forced air-cooling system does a great deal to dissipate the heat generated. The projector is reversible; the rewind normally supplied is an un-geared, hand type, but it can be replaced by a geared one. As is usual with 16mm. projectors, the capacity of the



The Bell & Howell Filmo Projector, with Kodacolor attachment, above.

(A) Opening for auxiliary condenser. (1) Condenser; (2) Auxiliary condenser, and (3) Kodacolor projection lens.

The Bell & Howell Filmo Projector

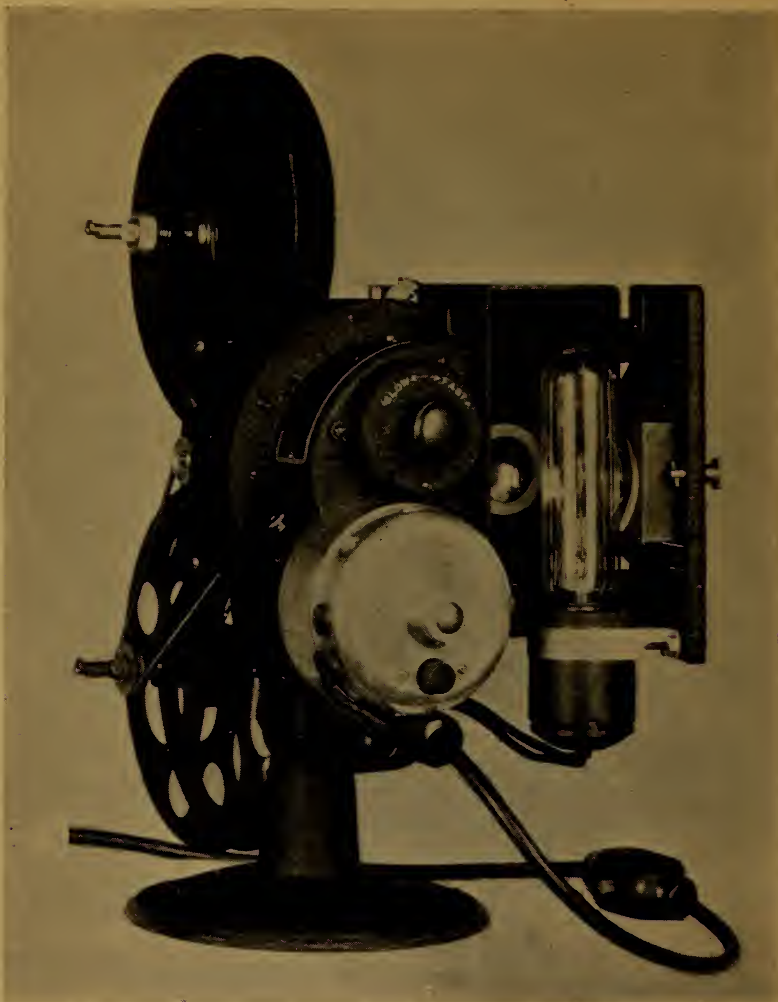
The Victor Cine Projector.

Filmo projector is 400 feet of film, but special attachments are made by the maker and by certain accessory specialists, by which the capacity can be increased to 1000 feet or 1200 feet, giving practically an hour's continuous performance. Probably the most important feature of this projector is the complete interchangeability of its lens equipments, for lenses ranging from ¾-inch to 4-inches in focus can be fitted, and the power of its 250-Watt lamp, combined with its excellent optical system, permits the screening of pictures as large as 7x9 feet. The *Filmo* projector can be adapted to Kodacolor, which it projects brilliantly.

Another projector of the pedestal type is the *Victor.* This projector is particularly famous for being easy on the film, and its outstanding feature is an automatic trip which stops the motor and turns off the light if the film fails to track properly. Another important feature is the fact that the shuttle which actuates the film-moving mechanism can be adjusted to compensate for wear, ensuring permanent steadiness regardless of the age of the projector. The mechanism of the latest models is positively, gear-driven, and extremely silent and accurate. The lamp-house is placed directly behind the film, with the shutter between it and the film, and, although the lamp used is only a 200-Watt bulb, the optical system is such that extremely brilliant results can be had even when projecting a large picture. The usual reverse mechanism is fitted, but, as there is no still-picture safety-shutter, single frames should not be held in position longer than 30 seconds. The rewind mechanism of the *Victor* is unique, for the spindles carrying the regular feed and take-up reels are extended on the opposite sides of their supporting arms so that one reel may be rewound while another is being projected—a very considerable advantage at all times, but especially so when a reel is to be repeated later in the same programme. A hand rewind is also provided. This projector is supplied in a carrying-case, the bottom of which is attached to the round base of the projector's pedestal to form a more convenient base; this base may be detached at will, however, as may the bottom of the pedestal, for which a large tripod may be substituted. The models of the Victor projector are available, differing only in finish and price, while special equipments are made to adapt either to different sources of current.

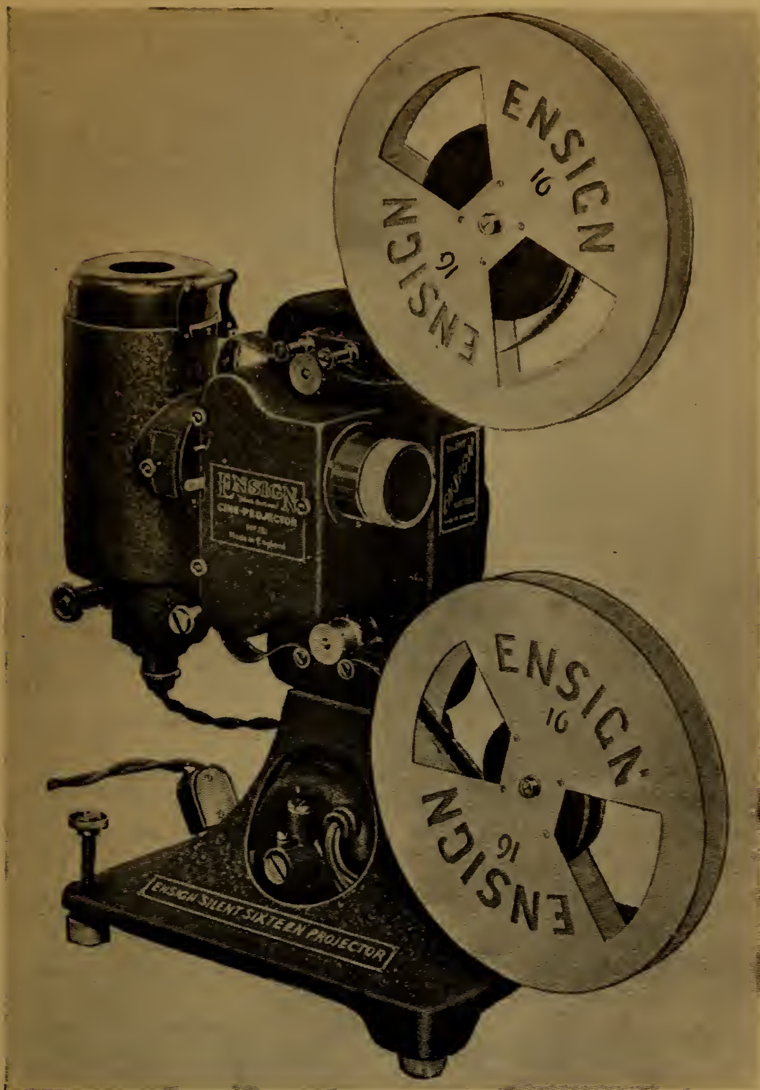
An excellent European projector is the *Ensign "Silent Sixteen."* This is a very fine machine, although it lacks some of the minor features general in American machines—such as reverse movement and a still-picture projection shutter—but its capabilities as a projector are in no way lessened by the absence of these niceties. It is of the pedestal type, with the motor mounted in the base. The units are conventionally arranged, with the lamp-house behind the film. The lamp is a 100-Watt bulb, but it is used in conjunction with a powerful condenser and a lens working at F:1.8, making possible a satisfactorily illuminated picture as large as 7x9 feet. One feature which particularly differentiates it from most American practice is the fact that all the electrical equipment and controls—the resistance-unit, switch, and lamp and motor-controlling rheostats—are grouped in a completely separate unit and may be located several feet away from the projector itself. Another unusual feature is the fact that instead of the safety-shutter's being translucent, though heat-proof, as is customery here, it is opaque, like the fire-shutters of theatrical projectors.

Two other European equipments deserve mention here, even though they are seldom seen as yet in America. These are the *Zeiss-Ikon* (German) and the *Bolex* (Swiss). The *Ziess-Ikon* projector is a fitting companion to the camera bearing the same name, which is already well known here. For a 400-ft. projector it is



Rear View of the Victor Projector, showing lamp-house, motor-control, and automatic rewind

just as compact as the camera is in its way. Much of this compactness has been secured by placing the two reels side by side *below* the projection-head, and by placing the lamp-house beside the film rather than behind it. Another outstanding feature is that all the controls are grouped around the film-channel, within a radius of a few inches. All of the usual movements are provided, including a still-picture projector; and a further remarkable feature is that the projector may be hand-cranked in an emergency. The *Bolex* projector is more conventional in appearance, but it has one feature that is absolutely unique: *it is instantly convertible to either 9.5mm. or*



From England: The Ensign "Silent Sixteen" Projector.

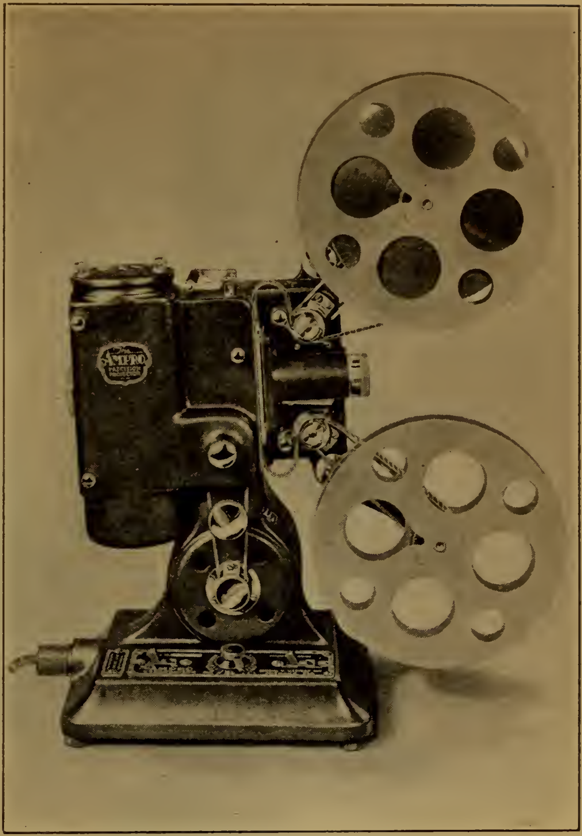
16mm. film. This makes it of tremendous value to the amateur who uses both standards, who is changing from one to the other, or who, though he may use one standard himself, would like to be able to run the films made by others, or rented from libraries, on the other standard. The *Bolex* is the answer to the problems of such people, and is reported to be equally efficient with either sized film.

Returning to the American productions, we have the well-known Q. R. S.-DeVry, which is one of the most popular of the lighter 16mm. machines. It is of conventional design, mounted on a base which houses the motor, controlling rheostat, single-picture clutch, and the elevating feet. The lamp-house is placed at the side, its beam being focussed on the film by means of a prism reflector; this firm having been one of the first to use such a construction. It is

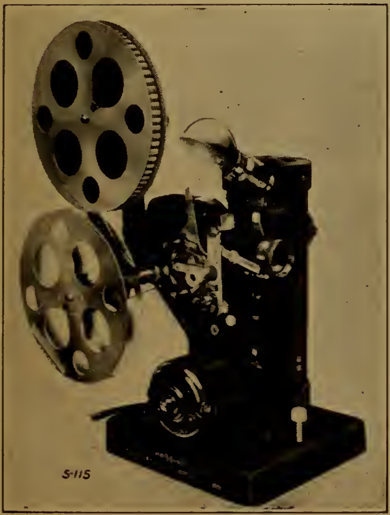
The DeVry Projector.

also almost the only American projector capable of being hand-cranked in case of need. The film movement is positive, though actuated by only one claw. Rewinding can be done either by motor or by hand. The lamp supplied is either 100-Watt or 200-Watt, as desired.

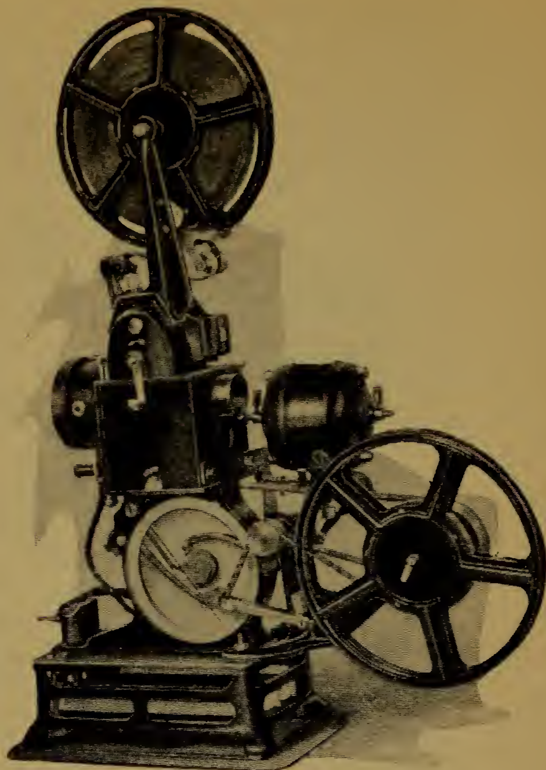
The latest entry in the field of home movie projection is the exceedingly neat and efficient *Ampro* projector. This is made in two models, one using a 200-Watt lamp and the other a special 250-Watt one. The optical systems are such as to get the absolute maximum of screen illumination out of either of these sources. To this end the lamp-house is placed conventionally behind the film. The other units are arranged conventionally, but the internal construction of the machine strikes a new note, inasmuch as all gear trains are arranged so that metal runs against fibre, reducing noise and minimizing wear. The movement is unique as it has a 9½ to 1 ratio, and an entirely new type of tension system, which consists of two independent edge-tension plates operating within the main pressure-plate. This arrangement, by controlling a considerable length of film on either side of the aperture yields greater steadiness with lessened wear on the film. The centralized controls of the *Ampro* are also unique. All the controls—the switch, the forward-reverse control, and the speed-controlling rheostat are



The Ampro Projector, above, a newcomer of excellent promise.



Left, the Kodel Projector, which will handle both the films made with the Kodel Camera, and those made by ordinary methods.



For 9.5mm. Film: the Pathex Projector, fitted with the Super-Reel attachment.

all grouped together on the base-plate. The tilt knob is directly above, with the stop button for still projection just above it, and the framer, which acts behind the film, just above that. The rewind is unusually simple, as all that is necessary is to thread the film into the reel it has just been removed from, and throw the projector into reverse.

As a companion to the revolutionary *Kodel "Homovie"* camera there is the *Kodel "Homovie"* projector, which is made with the same zig-zag movement as is used in the camera. The projector, however, can also be used for projecting normal 16mm. films. It has a 250-Watt lamp, whose beam is reflected onto the film. The machine is equipped with a still-projecting safety-shutter, and has all the customary refinements.

In the 9.5mm. field, *Pathex* is the sole American representative, just as in the field of 9.5mm. cameras. This firm produces a single model of projector, which, by virtue of an attachment for increasing its capacity, may almost be said to do duty as two distinct models. The first model is the regular *Pathex* projector, and is limited to the use of 30-ft. or 60-ft. rolls. It is motor-driven, and it coaxes an amazing brilliancy out of its tiny bulb; it will cover screens 36x42 inches or more, perfectly. A hand-driven version of this model is also available, which may be equipped with a motor at any time. The rewinding on both of these models is done by hand. The other model of the *Pathex* projector is termed the *Super-Reel* model. It is identical with the one just described save that it provides for the use of reels carrying 300 feet of film. In it the rewinding is also done by hand, though a powered rewind is supplied for those models using the auxiliary motor. A special dynamo is supplied for the *Pathex* for use where no current is available; this dynamo is driven by hand, and supplies current to the lamp, while it is belted to the drive-shaft of the projector, and thus furnishes the power for moving the film as well as for illuminating it.

THE DUSENBERY SYSTEM OF ESTIMATING EXPOSURE

H. Syril Dusenbery

IN ORDER to have an intelligent understanding on the subject of exposure it is first necessary to know just how the sensitive film emulsion records the image. We are all familiar with the fact that this image is directly dependent on the light that reaches the film, not only the amount of light, but the quality as well. When sufficient light reaches the film so that the image formed when it is finally developed is a clear and faithful representation of the original subject, it is said to be correctly exposed. Movie makers will find that with a little practise and experience this goal of correct exposure is not difficult to attain.

The only light that reaches the surface of the film when a picture is made is the light that is reflected from the subject itself. It should be remembered that regardless of the general brilliancy of the light, it is only that portion of it which is reflected by the subject that is effective. Naturally dark subjects do not reflect as much as white ones. For this reason dark objects require more exposure. Also a subject in the direct path of the light will reflect more into the camera than a similar subject receiving the light at right angles to it. The color of the light reflected must also be considered since the ordinary emulsion is much more sensitive to blue colors than to red. While the many factors that enter into the matter seem to make it quite complicated, in actual practise it is surprising how quickly the eye can be trained to judge the proper exposure necessary to obtain good screen results.

It is strongly recommended that the movie maker use an exposure meter until he has trained himself to judge light conditions accurately. Select any type meter that appeals to you and stick to it. Do not change meters continually. The Cinophot and Dremophot meters are particularly recommended as they actually measure the light reflected from the subject. These meters give accurate results even in the hands of a novice. By doing a little systematic testing, you can quickly learn the shortcomings and errors in the readings of your meter. The matter of personal equation enters to a considerable extent with many types of meters as no two people see things exactly the same way. It is, therefore, suggested that your meter be tested and checked against actual screen results.

To test any meter, take an average scene, a street for example, and determine the exposture (lens setting) with it under the given light condition. Jot this down for future reference. Now shoot a few feet of film with this recommended exposure. This done, change the lens setting to the next larger opening and shoot again. Then change the lens setting once more, this time making it the next stop smaller than that originally indicated by the meter, and again shoot a few feet of film. Make notes of exactly what you have done. When the finished film is projected on the screen you can quickly decide which of the three shots appears the best and, by referring to your notes, you can then compare the lens setting that produced best results with the setting recommended by the meter originally. It may be that you are in the habit of reading your meter too high or too low. This simple test will show you at once. It should be repeated under different light conditions and with a variety of different subjects. Both the film and your notes should be preserved for future reference. While all film possesses considerable latitude, a little careful testing in this way will quickly demonstate that there is a very definite lens setting that gives the best results.

The old rule, "when in doubt over-expose," does not apply to film finished by the reversal process. Over-exposed film appears almost like transparent celluloid and the pictures are weak and devoid of detail. Under-exposed film, on the other hand, is dark and dense when finished. As the under-exposed film is the lesser of the two evils, the revised rules becomes, "when in doubt UNDER-EXPOSE." Incidentally, the use of a smaller lens opening will make the picture sharper and more distinct on the screen. It is, therefore, recommended that the smallest lens opening, consistent with the prevailing light conditions, be used at all times. In this discussion we are assuming that the shutter speed is constant and that the exposure is controlled exclusively changing the size of the lens opening or stop.

All things being equal a long shot requires *less* exposure than distant objects and the use of a slightly smaller lens opening is a close up. More light enters the camera when photographing distant objects and the use of a slightly smaller lens opening is suggested. On the other hand, do not fail to open up the lens at least one stop number when shooting a close up immediately following a long shot. It is to be remembered that when shooting close ups, especially with the larger lens openings, it is essential to have the lens correctly focused. To insure accuracy the distance from the camera to the subject should be carefully measured with a tape line. Professionals always do this and you should do likewise if you want your close ups to be needle sharp on the screen.

Late in the afternoon, especially in Fall and Winter, the sunlight becomes very rich in red rays. This light is very deceptive as it appears quite bright to the eye but is rather inactive photographically. Often the change in color of the light is so gradual that it passes unnoticed, but the sensitive film is not fooled and the result is the pictures are dark and under-exposed.

Many methods have been devised to aid in the estimating of correct exposure. Most of these methods are rather cumbersome and complicated. While it is recognized that the many factors that enter in the determination of correct exposure make it almost impossible to devise any "rule of thumb" method to fit all cases, the following original system, worked out by the present writer and published here for the first time, will under ordinary normal conditions, give a remarkably close approximation. The simplicity of this new system makes it easy to memorize. It is based on the use of 16 mm. reversible film. Normal shutter speed and average summer light conditions and subjects are each divided into four general groups. Memorize them! You then have the entire system at your finger-tips.

The Dusenbery System

LIGHT CONDITIONS	SUBJECT CLASSIFICATIONS
1—VERY DULL. Overcast sky with heavy black clouds.	1—HEAVY SHADE. Subjects under trees, on porches, etc.
2.—DULL. Generally cloudy with no direct sun light.	2—STREETS and buildings. Subjects partly in the shade.
3—BRIGHT. Sun shining thru thin clouds or light haze.	3—*Open Landscapes,* White Buildings, sports and scenes without shade.
4—BRILLIANT. Strong clear sun light. No clouds or haze.	4—SEA, SKY, SNOW and Beach subjects reflecting strong light.

To estimate exposure under this system using the above classifications, simply multiply the number of the light condition by the number of the subject class. The result is the lens setting in the "F" system! In the event that there is no lens marking that corresponds to the result thus obtained, it will be satisfactory if the next nearest lens marking is used. For example, the exposure for an average street scene in brilliant light is obtained by multiplying 2 by 4. The result 8 indicates that stop F.8 should be used. In the case of an open landscape with dull light, multiply 3 by 2. The result is of course 6. The nearest standard lens marking to 6 is F.5.6. While this system must be used intelligently, the accuracy of the results are almost uncanny. All who have given this system of rapid estimation of exposure a trial have enthused over it and it is hoped that this method will help the movie maker to solve his exposure problems. It is not intended that this take the place of an exposure meter. It merely serves as a guide to those desiring to estimate exposure quickly when no meter is available.

No mention has been made in this discussion as to the use of color filters. Every filter is marked with a definite factor by its manufacturer. This factor is usually given for both ordinary film and panchromatic film. The deeper the tint of the filter, the more the exposure. Full directions usually accompany every filter. It is suggested that the subject of exposure without filters be mastered first and then no difficulty will be experienced when filters are used.

In no other phase of movie making is the old saying "practice makes perfect" true. Correct exposure is merely a matter of practice. Keep a record of the exposure given to your pictures and in a surprisingly short time you will find that you have mastered the subject of exposure.

MICRO-CINEMATOGRAPHIC APPARATUS

*Heinz Rosenberger**

MANY an amateur who owns a 16 mm. motion picture camera would like to extend its possibilities in photographing objects which others have not as yet taken. For those who can afford to travel this is not difficult, and it gives one a great deal of satisfaction to bring home and demonstrate to friends scenes of strange people, beautiful scenery and many wonders of nature.

But it is not at all necessary to venture out and travel in order to take scenes of interest and beauty. There is an immense field almost unexplored by amateurs and scientists as well, that is, the world behind the microscope. Those who have never looked into one have certainly missed a really worth while experience. Every drop of stagnant water from a little pond or river is the center of many happenings. Thousands of tiny creatures, the largest smaller than a needle head, perform their dances or eat smaller creatures. Their activity is exciting as one can follow them and observe what they will do now and later. But what is most fascinating is the fact that they are all clear as if made from glass. One can see right through and observe the little organs inside better than with an X-ray machine.

In some of them a little heart may be seen beating rapidly or a little stomach, always active, digesting food which very frequently is composed of still smaller animals. Others have a little stirring apparatus resembling the wheels of a watch (for instance rotifiers) which seem to rotate rapidly in order to bring the food closer to their mouth.

One can observe the stream of life everywhere and even in plants by following the protoplasm circling in the cells. It is even possible to see the formation and growth of crystals, and by using polarized light one obtains colors of a combination and brilliancy never seen before, a good subject for color photography.

It may be mentioned that microscopic motion pictures are used quite extensively in the scientific laboratories and universities. The advantages are quite obvious if one considers the time and work which would be necessary to demonstrate to an audience a phenomena which takes place under a microscope. It would be impossible to show it simultaneously to a number of people. But how easy it is to run a motion picture projector and at the same time explaining the phenomena appearing on the screen.

But the micro film is not only used for demonstration; it is an aid to scientific research. The motion picture made it possible, through its domination of time, to lengthen or accelerate time. Time acceleration especially is very useful in microscopic investigations where certain objects, for instance growing and dividing cells, move so

* *Rockefeller Institute for Medical Research.*

slowly that the human eye cannot perceive them. By taking single exposures at time intervals, for instance 1, 2 or 3 per minute, and by showing them through the projector at normal speed, 16 per second, the motion of these cells are translated into understandable speeds.

These are just a few possibilities for microscopic motion pictures, but the fact is that the field of adventure in this world of wonders is unlimited.

In order to give the owner of a 16 m/m. camera the opportunity to take motion pictures through the microscope, the author has designed a little apparatus (Fig. 1), which is the result of many years of experience in this field.

The microscope (any make) is placed on the base plate and brought in line with the center of the opening of the camera holder, which is screwed without the lens on the swivel plate, to the left so that the focusing lens is in line with the microscope. After the object is sharp in focus and the beam of light adjusted properly by looking into the ground glass, the camera is swung back in position and the picture can now be taken. By using a so-called beam splitter the object can be observed while the picture is being taken. All this is made so easy with this outfit that anyone can take microscopic motion pictures without difficulty. Any make of camera can be used with this apparatus, be it hand or motor driven.

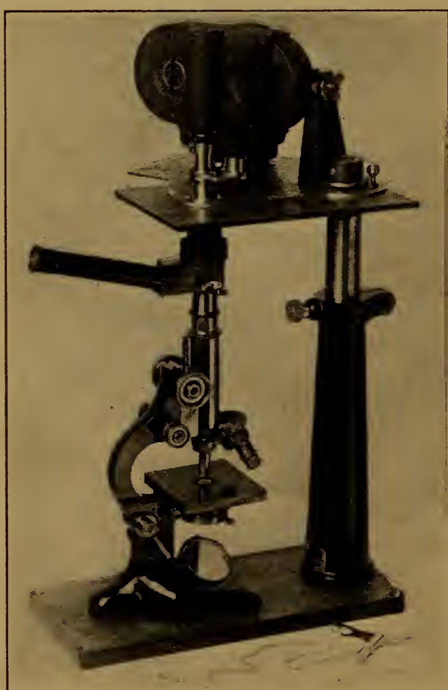
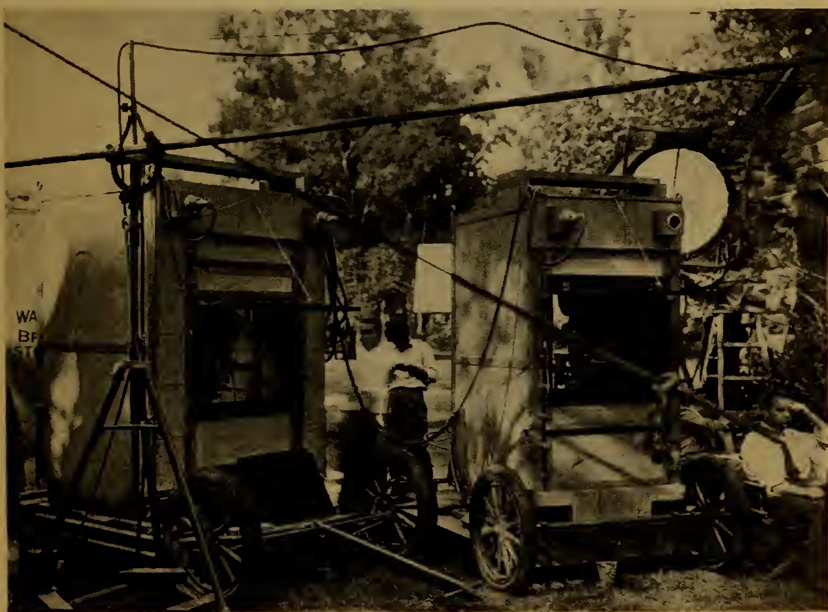


Fig. 1.

WHAT THEY USE IN HOLLYWOOD

IN THE following pages we are presenting a varied collection of pictures of the technical and mechanical gadgets and equipment developed in the picture industry and now in use in the big studios of Hollywood. To those readers who are many thousands of miles from the picture making center we feel that these pictures with short explanations will be of some assistance. At least, it will keep the readers in touch with just what is going on, in the equipment line, in Hollywood.

We are including lighting equipment, some sound devices, camera booths and other contrivances brought about by the advent of sound. From year to year we hope to make this one of the most interesting sections of this publication.—The Editor.



Two camera booths lined up for a scene at Warner Bros. Studio. Also note the microphone boom which is in great favor at Hollywood.

Rather ghost-like is the appearance of some silencing devices used in the Hollywood studios since the advent of sound. Here we have a group of cameras used at the Fox Studios in making "Song o' My Heart." The "horse-blankets" are used to prevent any camera noise from reaching the microphone.

Here we have the Mole-Richardson metal camera tripod for adapting standard camera tilting heads. Since the weight of the cameras has been increased tremendously by such silencing devices as is shown around the camera in this picture, the tripod here shown has become almost indispensable as it makes for ease in raising and lowering and also gives portability. Karl Struss, A. S. C., at camera.

Moviola sound and picture synchronizer for double film systems. This device is used in editing pictures in which sound is recorded on separate films.

Even diving suits are now used by cameramen of Hollywood. Here is Joseph August, A. S. C., going down into the Pacific Ocean to shoot a special under-water scene. The box he has is a watertight camera he designed for such work.

Another silencing device being used in Hollywood is the one pictured above.

One of Paramount's camera booths of portable type is shown above. The door has been removed, showing how the camera fits within. This silencing device has met with much success at the Paramount Studios.

A blanket silencing device for cameras used by the James Cruze Productions is here shown in operation on an exterior scene.

The old and new in the matter of cameras is shown in this picture. The antiquated camera at right was used in 1913 to make C. B. de Mille's first picture. The other is the modern camera in a "bungalow," as the silencing covering is called.

The monitor room on one of Universal's big sound stages. Here the "mixer" does his work.

Shooting an exterior in a talkie at Pathe. Note the microphone hanging from the boom. Dewey Wrigley, A. S. C., is at the camera with its silencing covering that looks like a block of asbestos.

Three of the new camera mounts used at Paramount for talkies. At left is a "blimp," or portable tripod. Center is "blimp" on a baby tripod. Right is a camera mounted on rubber-tired truck.

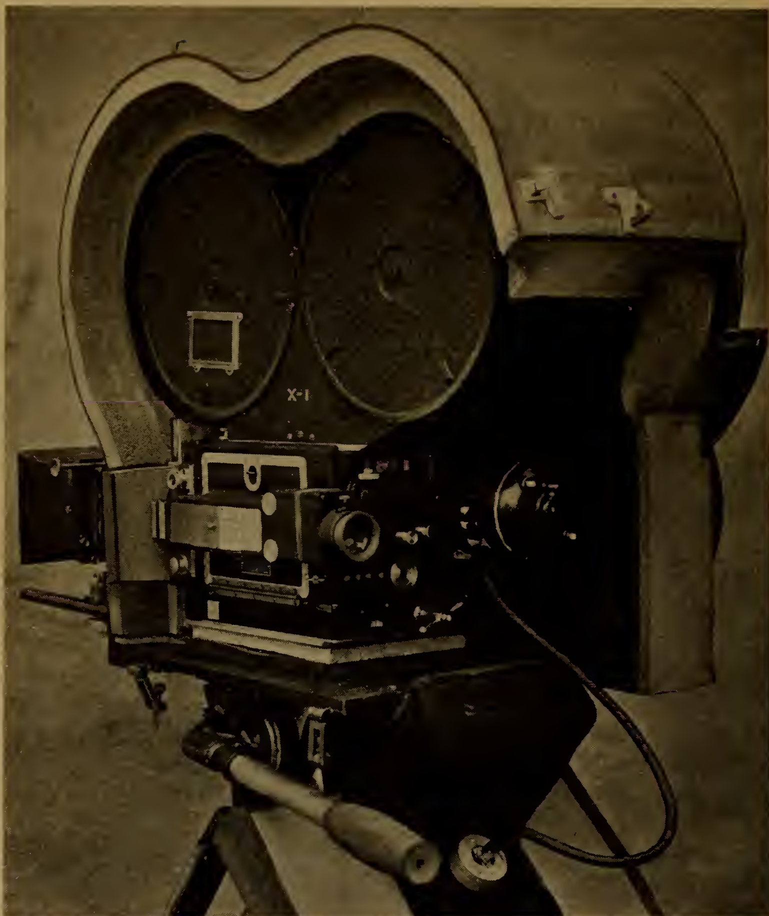
Here is the silencing device for camera used in Christie Pictures at Metropolitan Sound Studios.

Caught in Africa, Clyde De Vinna, A. S. C., devised the above silencing equipment for his cameras on "Trader Horn," for M-G-M. De Vinna is the man with the pipe. The guns were on hand in case of lions.

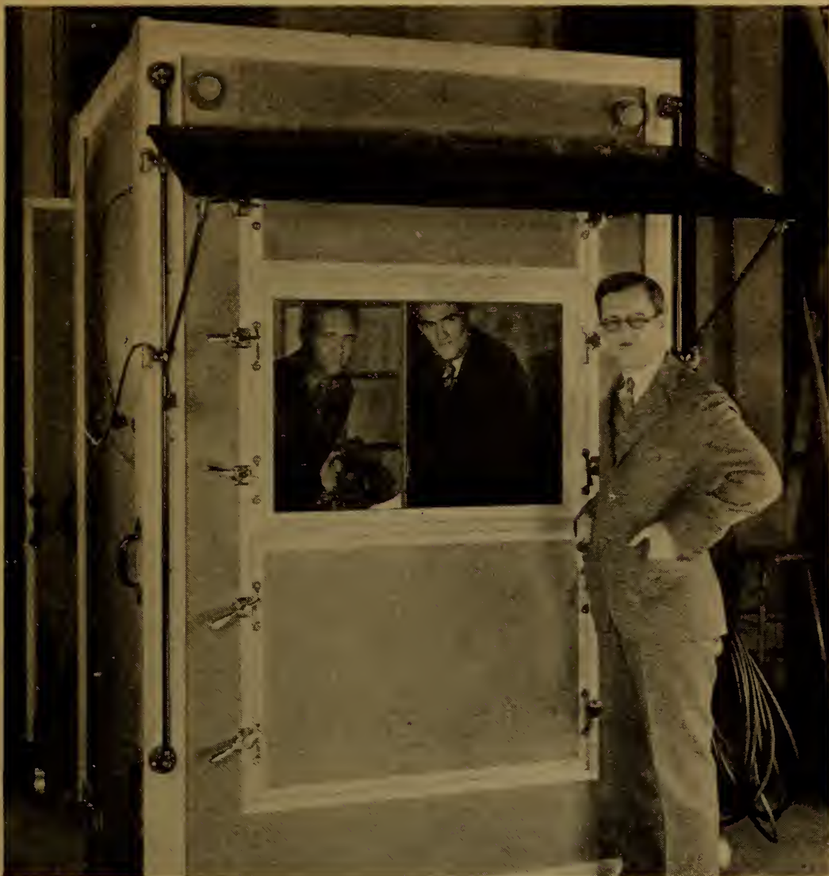
Here we have a camera booth and microphone boom in use on location for a Warner Bros. picture. The microphone boom puts the microphone just where it is wanted quickly and silently.

Setting up for an exterior for a Pathe picture. Note the silencing cover being carried to the camera of Edward Snyder, A. S. C. Again the ever-present microphone and boom.

The camera booths of portable type even go out into the country as is here shown. This is a Paramount unit. Note the microphone dangling on a rope.



Above is shown the device developed at R-K-O Studios for silencing the camera. The housing has an exterior of sheet rubber with a thick inner lining of sponge rubber. This type of silencing device eliminates booths such as is shown on the opposite page.



The "ice-box" type of camera booth. There are many booths of this type in use in Hollywood; but they, naturally, cut down portability.

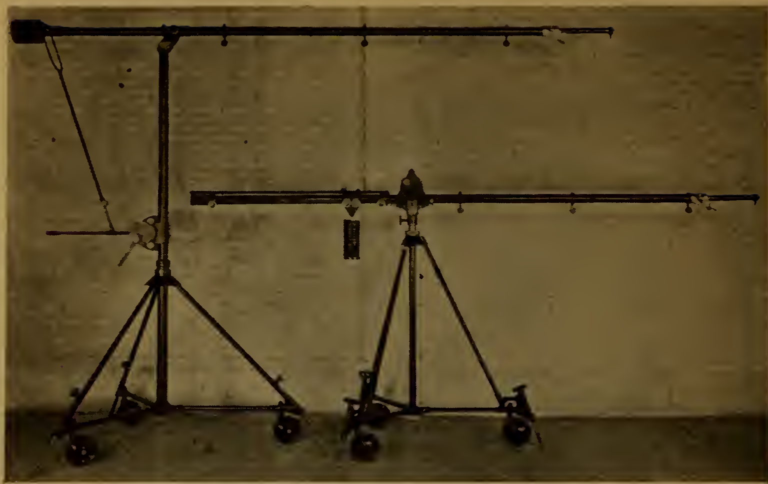
A 24" Sun Spot incandescent lamp that meets with favor in Hollywood.

For Aerial Photography

For aerial work some Hollywood cameramen have devised a combination of two cameras as shown above. They can get two negatives in this manner. Elmer Dyer, A. S. C., is the man at the camera above.

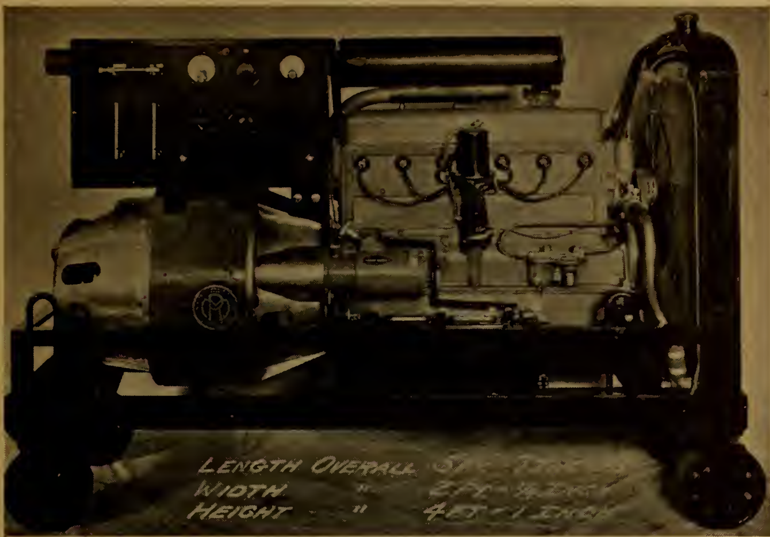
A group of nine Mole-Richardson Bell Flood lamps, incandescents.

Another M-R incandescent that is being used extensively. This is a Bowl lamp.



Here are two of the famous microphone booms which have come into so much favor during the past year.

A 4-unit Dimmer Bank developed by Mole-Richardson. Note method of interlocking.

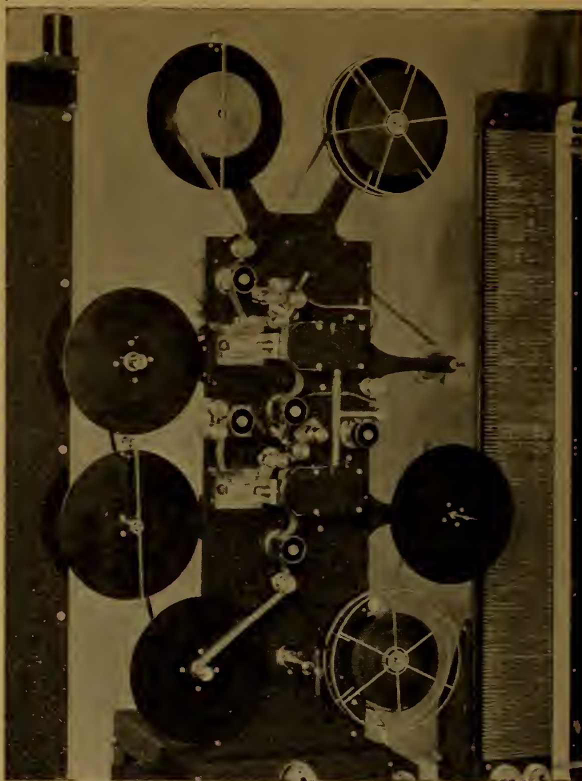


Here is a motor generator set with a carrying capacity of 200 amperes.

Above is another new device. It is a tilt head mechanism on a Rohing Tripod.

A 2000-watt studio spot.

A 36″ Sun Spot that was introduced to the picture industry during the past year.



Here is the new printer developed and built by Oscar B. Depue. This ingenious machine simultaneously prints sound and picture and is one of the most important mechanical contributions of the past year to the industry.

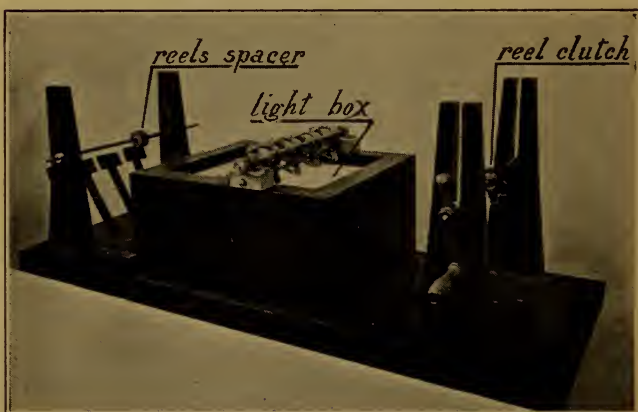
This illustration gives a fair idea of the enormous amount of equipment that is now being used in the making of pictures. Note the amount of lights.

First Sound-on-Film Double Exposure

WHEN sound pictures arrived fear was expressed that double exposures would be no longer possible. Cinematographers soon solved the problem. Here, above, we have a scene from The Fox Movietone picture, *Masquerade,* shot by Charles Clarke, A. S. C. This is a double exposure of voice and actor. The two men are one and the same, Alan Burmingham. This was the first dual role of Movietone. Cinematographers now do everything they did in silent drama days in Hollywood.

A device perfected by Frank Cotner, A. S. C., for mounting camera on automobile.

Multiple synchronous rewind system for use in editing sound-on-film pictures.



A Practical Gadget.

WITHIN the past two or three years, as cameras have grown heavier and heavier, and been encased in all manner of booths, bungalows, etc., for sound photography, the problem of properly supporting them on their tripods has become increasingly acute. This is particularly true in cases where the tripod has to be held down with turnbuckles, and when 'baby' tripods are used. The small thumbscrews that were formerly adequate to prevent the tripod-legs from telescoping upon themselves are now entirely unequal to the strain. It is impossible to tighten a small thumbscrew to a point where it is absolutely certain to withstand the weight of the new, heavy 'blimp' cameras, and the added pull of the turnbuckles.

Therefore, in my recent work I have found this a very practical method of ensuring the stability of a camera set-up. I have the legs of my tripods drilled with small holes at the various heights most frequently used, and after setting up, I slip small, iron spikes to the tripod with leather thongs, I can be assured of having them always handy, and by their use, I can be certain that my tripods will not slip in the middle of a scene.

—*Karl Struss, A. S. C.*

Tinting and Toning Motion Picture Film

IN THE production of motion pictures it is often desirable to vary the color of the film either by tinting or toning or by a combination of the two processes.

Tinting, as usually understood, consists in immersing the film in a solution of dye which colors the gelatin, causing the whole picture to have a uniform veil of color on the screen. In commercial production this effect is most frequently secured by the use of positive film coated upon a base of colored celluloid. A great variety of tints are commercially available in both nitrate and acetate stocks, in all widths from 16mm. to 70mm.

Toning consists in either wholly or partially replacing the silver image of the positive film by some colored compound, so that the clear portions or highlights of the image, which consist of plain gelatin, remain unaffected and colorless, but the remainder of the image is colored.

Combinations of tones and tints are possible, and produce many beautiful effects.

Tinting

When tinting with dye solutions, the dye colors the gelatine layer, whereas in the case of tinted base film, the film base itself is colored.

Success in tinting depends on the correct choice of dyes and the correct methods of their application.

Dyes are of two kinds, acid and basic, depending upon their chemical composition, acid dyes being alkali salts of organic acids, while basic dyes are the chlorides, sulphates, etc., of organic bases.

In view of the opposite nature of acid and basic dyes, it is obvious that, if several dyes are to be mixed one with another to produce intermediate tints, they must all be of the same class. Since the number of acid dyes are usually more stable to light, they are the most suitable for tinting.

The equipment necessary for systematic tinting or toning is essentially the same as that required for development, consisting of the usual tanks and racks, or small drums, or the usual processing machines. The drum system is not to be recommended for large-scale operations, though for individual use it is most efficient and economical. In any case it is advisable that the equipment used for this purpose be used for it exclusively, and, if possible, occupy a separate room to exclude any chance of dye particles settling on wet film or dropping in the developing, fixing, or rinsing tanks. Similarly it is important never to sift nor allow the dyes to be blown into the air when weighing them out, and the mixing rooms should hence be located as far as possible from those in which wet film is handled.

Racks and tanks used with each solution should be kept separate to prevent their contaminating the baths of other solutions.

Waterproofing of wooden racks can be accomplished either by impregnating the wood with paraffin wax or by treating with a nitrocellulose lacquer. Painting, varnishing, or treatment with wax solutions is ineffective.

The following American-made dyes are the most suitable for dye-tinting, and offer a range of nine standard tints. In the cases where alternative dyes are recommended, they may differ slightly in color, rate of bleeding, etc., and they are therefore not strictly interchangeable. On the screen, however, the difference between films dyed with alternative dyes is practically imperceptible.

TINT	DYE	MANUFACTURER
Cine Red	Amaranth 40-F	National Aniline & Chemical Co., New York
	Azo Rubine	White Tar Aniline Corp., 56 Vesey St., New York
Cine Scarlet	Croceiи Scarlet MOO	National Aniline & Chemical Co., New York
	Scarlet G. R.	Levinstein, 74 India St., Boston, Mass.
Cine Orange Red	Lake Scarlet R	National Aniline & Chemical Co., New York
Cine Orange	Wool Orange GG	National Aniline & Chemical Co., New York
Cine Yellow	Quinolin Yellow	National Aniline & Chemical Co., New York
	Wool Yellow Extra Conc.	National Aniline & Chemical Co., New York
Cine Light Green	Naphtol Green B Conc	White Tar Aniline Corp., 56 Vesey St., New York
	Naphtol Green M	National Aniline & Chemical Co., New York
Cine Green	Acid Green L	National Aniline & Chemical Co., New York
	Fast Acid Green B	National Aniline & Chemical Co., New York
Cine Blue	Direct Blue 6B	National Aniline & Chemical Co., New York
	Niagara Sky Blue	National Aniline & Chemical Co., New York
Cine Violet	Fast Wool Violet B	National Aniline & Chemical Co., New York
	National Violet 2RD	National Aniline & Chemical Co., New York

The following formulas for tinting are suggested:

FOR USE AT 65° F. (18° C.)

TINT NO.	DYE	AVOIRDUPOIS		METRIC		TIME
1.	Cine Red	33	ounces	1000	grams	3 minutes
	Water to	50	gallons	200	liters	
2.	Cine Red	13	ounces	400	grams	3 minutes
	Water to	50	gallons	200	liters	
3.	Cine Scarlet	13	ounces	400	grams	3 minutes
	Water to	50	gallons	200	liters	
4.	Cine Orange-Red	13	ounces	400	grams	3 minutes
	Water to	50	gallons	200	liters	
5.	Cine Orange	6½	ounces	200	grams	3 minutes
	Cine Scarlet	145	grains	10	grams	
	Acetic Acid (glacial)	3¼	ounces	100	cc.	
	Water to	50	gallons	200	liters	
6.	Cine Orange	6½	ounces	200	grams	1 minute
	Acetic Acid (glacial)	3¼	ounces	100	cc.	
	Water to	50	gallons	200	liters	
7.	Cine Yellow	13	ounces	400	grams	1 minute
	Acetic Acid (glacial)	3¼	ounces	100	cc.	
	Water to	50	gallons	200	liters	
8.	Cine Light Green	26	ounces	800	grams	3 minutes
	Water to	50	gallons	200	liters	
9.	Cine Green	26	ounces	800	grams	3 minutes
	Water to	50	gallons	200	liters	
10.	Cine Blue	13	ounces	400	grams	3 minutes
	Water to	50	gallons	200	liters	
11.	Cine Blue	13	ounces	400	grams	1 minute
	Water to	50	gallons	200	liters	
12.	Cine Violet	13	ounces	400	grams	3 minutes
	Water to	50	gallons	200	liters	

The strength of the bath and the time of tinting can be adjusted to meet individual requirements.

The dyes should be mixed in glazed earthenware or enameled iron pails or crocks, using warm water when necessary. A separate wooden paddle should be used when mixing each dye, and washed thoroughly after using.

Dissolve the solid dyes in as small a volume of hot water as is possible, and filter through fine muslin. Pour hot water over any residue remaining, so that all the dye will be dissolved, and dilute the solution in the tank to the required volume at 65°F (18°C.)

The depth of the tint depends on the following factors:

1. *The Nature and Strength of the Dye Bath.*
2. *The Temperature of the Dye Bath.*
   Although temperature has little effect on the rate of dying with the dyes recommended, when used without the addition of acid it is always advisable to work between 65° to 70°F. (18° to 21°C.) for uniform results.
3. *The Time of Dyeing.*
   This is an important factor. The time of dyeing depends somewhat on the previous handlings of the film, as film fixed in a bath containing potassium or chrome alum dyes more quickly than film fixed in plain hypo and hardened with formalin.

Should the film for any reason be over-dyed, some of the dye may be removed by immediately washing for 10 to 15 minutes.

About 20,000 feet of film per 50 gallons of dye bath may be dyed. As the rate of dyeing slows down, the bath should be revived by adding a concentrated solution of the dye, and not by adding acid. When the bath becomes muddy, especially in warm weather, it should be renewed.

If uniform results are to be had, the film should never be passed through the projector before tinting or toning.

Toning

As distinct from *tinting*, a *toned* image consists of a colored image embedded in a layer of colorless gelatin, so that while the highlights are clear, the shadows are colored.

The coloring matter may consist of an inorganic colored compound (metallic salts) or a dye, or a mixture of both. The toned image is produced by wholly or partially replacing the silver image with one or more of these substances. The colors used in toning are necessarily very transparent, and therefore tones can only be judged by screen projection.

Of the various metal salts, uranium ferrocyanide (brown), iron ferrocynaide (blue), and silver sulphide are the most suitable.

Silver sulphide gives a blue-black tone when applied to a print of *normal* density, but when applied to a *thin* or *medium* print it gives a brown tone. It is commonly known as a *sepia* tone. It is applied by first bleaching in the following solution:

		(AVOIRDUPOIS)	(METRIC)
A.	Potassium Ferricyanide	8¼ lbs.	4000 grams
	Potassium Bromide	2 lbs. 1 oz.	1000 grams
	Water to	50 gallons	200 liters

Bleach thoroughly in this until the image appears uniformly yellow on looking at the back of the film. Then wash for 5 minutes, and tone in:

B. Sodium Sulphide (crystal)	2 lbs. 1 oz.	1000 grams
Water to	50 gallons	200 liters

Temperature of baths: 65° to 70° F. (18° to 21° C.)

Time of Bleaching: Two to four minutes.

Time of Washing after Sulphiding: Ten to fifteen minutes.

Life of Baths: Bath A keeps well in the dark; solution B will keep almost indefinitely.

Uranium toning is a single-solution process, and consists of:

Uranyl (Uranium) Nitrate	16½ ounces	500 grams
Potassium Oxalate	16½ ounces	500 grams
Potassium Ferricyanide	6½ ounces	200 grams
Ammonium Alum	2½ lbs.	1200 grams
Hydrochloric Acid (10% sol.)	1 quart	1000 cc.
Water to	50 gallons	200 liters

Mix in the order given. The solution obtained should be perfectly clear and pale yellow in color.

It is convenient to keep 10% stock solutions of the above, from which a new bath may be compounded quickly when needed. A 10% solution of Hydrochloric acid is one containing 10 parts by volume of the concentrated acid in 100 volumes of the final solution.

Temperature of Toning: 65° to 70° F. (18° to 21° C.)

Time of Toning: For maximum effect, 10 minutes, during which time the tone passes through a series of changes from brown to red. By withdrawing the film at any shorter interval, any intermediate tone desired can be obtained. As this bath intensifies the image considerably, the type of print used for theese intermediate tones should be carefully adjusted to the time of immersion in the toning bath needed to secure that tone. This chart is a safe guide to work from:

NATURE OF PRINT	TIME OF TONING	COLOR
Normal	2 Minutes	Chocolate
Medium	5 minutes	Warm Brown
Thin	10 minutes	Reddish Brown

Time of Washing: Ten to fifteen minutes. In this time the highlights will become clear, though a thin yellowish-brownish veil may remain in the clear gelatin as a result of the intensification of minute traces of fog: this has no effect on projection. Washing should not be prolonged, especially if the water is inclined to be alkaline; as the toned image is soluble in alkali.

Life of Bath: Fifty gallons will tone about 5,000 feet of film, after which the rich tone tends to flatness. At this point the bath may be revived by adding acid to the extent of the original amount, after which a further 5,000 feet of film may be toned. After this stage the bath becomes exhausted rapidly, and should be thrown away.

Iron Tone (Blue):

Ammonium Persulphate	3¼ ounces	100 grams
Ferric Alum (ferric Ammonium Sulphate)	8¼ ounces	250 grams
Oxalic Acid	1¼ lbs.	600 grams
Potassium Ferricyanide	6½ ounces	200 grams
Ammonium Alum	2 lbs. 1 ounce	1000 grams
Hydrochloric Acid (10% sol.)	6½ ounces	200 cc.
Water to	50 gallons	200 liters

The method of compounding this bath is very important. Each of the solid chemicals should be dissolved separately in a small quantity of warm water, the solutions allowed to cool, filtered into the tank strictly in the order given, and the whole diluted to the required volume. The bath should be a pale yellow color, and perfectly clear.

Time of Toning: Two to ten minutes at 70° F. (21° C.) The color of the image varies from a light bluish-grey for short time toning (about 3 minutes) to a deep blue for maximum immersion.

Time of Washing: Ten to fifteen minutes, until the highlights are clear. A very slight permanent yellow coloration of the clear gelatin usually occurs, but should be only just visible. It has no effect on projection. Washing should not be unduly prolonged.

Life of Bath: If acid is renewed to the extent of the original amount after toning each 5,000 feet, the bath is capable of toning 15,000 feet per 50 gallons of solution.

A very pleasing tone is obtained by first toning in the Uranium bath for about 3 minutes and then in the iron bath for about 2 minutes.

Dye Toning

As the number of suitable colored metallic compounds is rather limited, other methods of toning have also been evolved. Certain inorganic compounds have been found to have the peculiar property that when immersed in a solution of a basic dye the dye comes out of the solution and attaches itself to the compound. The dye is then said to be *mordanted,* and the inorganic compound is called a *mordant.* Silver ferrocyanide is a typical mordant. Therefore if a silver image is converted into a silver ferrocyanide image, and then immersed in a solution of a basic dye, a mordanted dye image is produced.

The Mordanting Bath

Uranyl (uranium) Nitrate	10½ ounces	320 grams
Oxalic Acid	5¼ ounces	160 grams
Potassium Ferricyanide	5¼ ounces	160 grams
Water to	50 gallons	200 liters

The uranyl nitrate should be of good quality, and should not contain an excess of free nitric acid. First dissolve the chemicals separately in small quantity of water, then add the oxalic acid solution to the uranyl nitrate solution, and finally add the potassium ferrocyanide solution. After mixing, the bath should be light yellow and perfectly clear. Expose the solution to light as little as possible, as light causes the precipitation of a brown sludge of uranyl ferrocyanide.

Time of Mordanting: Immerse the film until a very slight chocolate colored tone is obtained. When the bath is new this will take from 1½ to 2 minutes, but as the bath ages, this time will be prolonged. If a concentrated stock solution of the mordanting bath is kept on hand a little of it may be added to revive the bath.

After mordanting 10,000 feet of film per 50 gallons, the bath should be thrown away.

The temperature of this bath should not be higher than 75° F. (24°C.)

Time of Washing after Mordanting: Wash until the highlights are free from yellow stain, which usually takes from 10 to 15 minutes. Do not prolong the washing for more than 20 minutes, or some of the mordant will be washed out.

The Dye Bath

All the dyes used (except Methyl Violet and National Pink) are compounded according to the following formula:

Dye	1 ounce, 140 grains	40 grams
Acetic Acid (glacial)	3¼ ounces	100 cc.
Water to	50 gallons	200 liters

Thoroughly dissolve the dye in hot water, filter into the tank, and fill up the tank with cold water.

With Methyl Violet, use one-fourth the quantity of dye called for in the above formula. With National Pink, use six times the quantity of dye called for in the above formula.

The following dyes are suitable for dye toning:

National Pink B	Pink
Safranine A	Red
Chrysoidine 3R	Orange
Auramine	Yellow
Victoria Green	Green
Methylene Blue BB	Blue
Methyl Violet	Violet

Time of Dye Toning: Immerse in the dye bath for from 2 to 15 minutes, according to the color desired. A short immersion gives a slightly colored image, and prolonged immersion gives a strongly colored image.

Modifying Dye-Toned Images

If over-dyed, some of the dye can be removed by immersing in an 0.2% solution of concentrated ammonia and rinsing before drying.

If after dyeing 10 minutes the image does not mordant sufficient dye, wash thoroughly, re-immerse in the mordanting bath, wash again, and then place in the dye bath.

Intermediate dye-tones may be obtained by immersion in successive dye baths, or by mixing of the dye solutions.

By omitting the ammonium alum from the Iron toning formula, the half-tones of the toned film are white and the shadows blue: if this film is then immersed in any of the basic dye solutions given above, the dye is mordanted to the half-tones, while the shadows remain more or less blue. The best type of positive for this purpose is one of medium density.

Time of Toning: Tone until the shadows are deep blue.

Time of Washing: Ten to fifteen minutes.

Time of Dyeing: Immerse in the dye-bath until the desired depth of color in the half-tones is obtained: this may be from five to fifteen minutes.

Safranine gives *pink* half-tones.

Auramine gives *yellow* half-tones.

Chrysoidine gives *Orange* half-tones.

Time of Washing After Dyeing: Until highlights are clear: from five to ten minutes.

Life of Bath: Same as that of the Iron toning formula.

Very pleasing effects may be had by combining tones and tints. The tints may be either chemical, or the result of the use of tinted-base film stock.

Tints and Tones for Amateur Use

All of the toning and tinting formula given above are suitable to amateur use on either reversal or normal positive films, of 16mm. or 9.5mm. standards. All that is necessary is to reduce the proportions of the solutions given to such as will make up the smaller quantities practical for individual use, and proceed according to the instructions given for professional use. However, a few special formulae and suggestions for amateur use are given here also.

For amateur use one method of getting tinted effects easily, and without altering the film, is by the use of special colored discs on the lens of the projector. Similarly, toned effects can be produced by the use of colored flood-lights played on the screen.

There are a number of photographic stains available commercially, which are suitable for tinting; and certain colored inks can also be used for the purpose, in suitable dilutions.

Any of the sepia toning compounds prepared for still photographic use, and sold ready-mixed, can also be used for cine toning. Similarly, the various other photographic tones—blue, red, green, etc., —put up by Burroughs Wellcome & Co., Ltd., will also serve for this purpose.

The following solution is also excellent for blue toning:

Ferric Ammonium C'trate	100 grains
Potassium Ferricyanide	100 grains
Acetic Acid (glacial)	2 ounces
Water to	35 ounces

When the desired tone is reached, wash until the highlights are clear. This solution serves to intensify the image, so, if possible, when making scenes on reversal film for this treatment, overexpose them a trifle.

For tones ranging from warm black through purple and brown to brick red, the following is a useful formula:

(A)	Copper Sulphate	30 grains
	Potassium Citrate (neutral)	120 grains
	Water	10 ounces
(B)	Potassium Ferricyanide	120 grains
	Potassium Citrate (neutral)	10 ounces
	Water	25 grains

Mix A and B in equal parts immediately before using. The separate water. Films intended for this treatment should have a strong image, as there is a definite reducing action. Toning takes place very slowly.

Tones from warm sepia to red are obtainable with the following Uranium toner:

(A)	Uranium Nitrate	25	grains
	Acetic Acid (glacial)	½	ounce
	Distilled Water	18	ounces
(B)	Potassium Ferricyanide	25	grains
	Acetic Acid (glacial)	½	ounce
	Distilled Water	18	ounces

Mix A and B in equal parts immediatly before using. The separate solutions keep indefinitely. If dry, the film to be toned should first be soaked in water before immersion in this bath, and, during immersion, be kept constantly on the move. When the desired tone is reached, the film should be removed to a stop-bath of 35 drops of acetic acid to 35 ounces of water. Washing should be done in still water, as running water is liable to wash out some of the color: the time of washing is until all trace of yellow is discharged. This is best used with rather thin images, as the action is somewhat of an intensifier.

Beautiful green tones are obtainable with this Vanadium Toner:

Vanadium Chloride (50% solution)	40	minims
Ferric Chloride	10	grains
Ferric Oxalate	10	grains
Potassium Ferricyanide	20	grains
Oxalic Acid (Saturated Solution)	2½	ounces
Water to	20	ounces

The oxalic acid solution is prepared by dissolving oxalic acid crystals in boiling water in the proportion of one ounce of water to every ounce of crystals. The solution should be allowed to cool. Add the ferric chloride and oxalate to the oxalic acid solution diluted in half the water, then add the ferricyanide, stirring well, and finally the vanadium. Tone until the color is slightly darker than required and then wash until the desired tone is reached. Any yellowish stain left in the highlights may be removed by a weak solution of ammonium sulpho-cyanide (2 grains per ounce of water). This toner has a considerable reducing action.

REVERSAL

Making Direct Positives

The making of direct positives, whether by the reversal-film process generally used by amateurs, or by converting an ordinary negative into a positive, consists in making a negative on a strip of film, developing it, and then printing that negative on the same strip and destroying the original negative chemically, but leaving the positive print to be developed, etc., in the usual way.

In 35mm. use, where regular reversal film is not available, either negative or positive film may be used, but where the light permits, positive is preferable, as it gives snappier results, although it is not corrected for color-values. As positive stock is far slower than negative, it can only be used under the best light conditions, and always with a much wider diaphragm opening than would be used with negative. It is not recommended for interiors. In any case, the exposure must be rather full.

The apparatus needed is a *solid* drum of metal or wood, painted with a dead black photographic enamel which must be resistant to the action of photographic chemicals. *A skeleton-type drum, with only ribs, cannot be used for reversal processing.*

Any high-contrast developer can be used. The following is a good formula:

Hydroquinone	1 ounce
Sodium Sulphite (Dry)	11 ounces
Sodium Carbonate (Dry)	7 ounces
Potassium Bromide	1 ounce
Water	1 gallon
Alcohol	1 pint

The alcohol may be omitted, but permits development at a higher temperature, giving greater contrast.

Development should be slow, by dim, red light, so as to give a snappy negative with pure whites and deep blacks. Be sure to develop fully.

Wash for five minutes or more, to remove all traces of developer.

At this stage, any swelling of the film should be taken up by tightening the film on the drum. Then the film should be exposed to a diffused, white light until the white portions of the film become visibly greyed.

The next step is to destroy the negative image by immersion in:

Water	1 gallon
Potassium Bichromate	1½ ounces
Nitric Acid	3 ounces

The film is immersed in this bath until the negative image has entirely disappeared, and only the creamy white of the remaining, undeveloped silver bromide is visible. After this, the film must be thoroughly washed, and the final, positive image then developed in the usual manner. This may be done in the same solution in which the negative was developed, or in some softer-working solution.

After this development, the print is fixed and washed in the usual manner.

Another set of formulae, especially intended for substandard reversal emulsions, are recommended by Messrs. Pathé for use with their Pathex system.

The formula for the first development is:

Paraphenylenediamene	150 grains
Sodium Sulphite (crystals)	1 ounce
Caustic Soda	150 grains
Potassium Bromide	60 grains
Phenosafranine (Solution 1:1000)	160 minims
Water	35 ounces

If *anhydrous* sulphite is used, only ½ ounce is needed. There are also several commercial desensitizers, such as "Desensol," etc., which can be readily substituted for the safranine solution required.

This developer must be used at temperatures between 60° and 65° F.

The developer should be filtered before use. Remember, too, that the caustic soda is bad for the eyes, so do not splash the developer.

In developing reversal film, the film should look almost opaque when the development is finished, and the black portions of the negative should appear of almost equal density from either side of the film. The following table will be useful in timing the development:

If the first signs of image appear in:	Develop for
Up to 20 seconds	5 to 8 minutes
30 seconds	10 minutes
40 seconds	12 minutes
1 minute	15 minutes
1¼ to 1½ minutes	20 to 25 minutes

Reversion is in this case carried out chemically, by use of the following reversion bath:

Potassium Permanganate	30 grains
Sulphuric Acid	170 minims
Water	35 ounces

The acid should be added last in a slow stream, stirring the while. Sodium Bisulphate (380 grains) may be substituted for the acid, but is not so effective.

In reversion the negative is dissolved away and the film takes on a red color. This normally takes from seven to ten minutes, but should in any case be continued until all of the black image is dissolved. If the amateur has both orange and red lights on his darkroom lamp, the red one may be removed after the film has been five minutes in this bath.

After reversion the film is washed until it becomes a clear yellow —usually about seven minutes. The remaining operations may be carried out in white light.

The next step is bleaching, by the following formula:

Sodium Sulphite (crystals)	150 grains
Sulphuric Acid	35 minims
Water	35 ounces

Immerse the film in this until the parts formerly densest become quite transparent. If there are found to be dark spots on the film, reversion is not complete: rinse the film thoroughly and return it to the reversion bath. Then wash, and bleach again.

The final step is darkening: this is done in a solution prepared by adding 150 grains of Sodium Hydrosulphite (NOT *hypo*sulphite) to the bleaching bath. The film is placed in this, and the image steadily darkens until a good, brownish-black positive is produced. It is important that the Sodium Hydrosulphite be perfectly fresh: otherwise the image may not darken sufficiently, or may turn an unsatisfactory sepia tone.

After darkening, the film should be thoroughly washed in running water—at least 15 minutes—and then dried. Each of these solutions is sufficient for about 30 feet of substandard film, although the developer will last for about 90 feet. The quantities given here are those intended for use in the tanks made by the Pathex people in Europe, which hold 26 feet of film (one full Pathex charger). They are not as yet available in America, but may be had either from MM. Pathé-Enseignement, 20 *bis* rue La Fayette, Paris, 9e, France, or from Pathescope, Ltd., 5 Lisle Street, London, W.C. 2, England. The solutions recommended can, of course, be made up in any larger quantity for use in larger tanks. Incidentally, the chemical type of reversion does not require a solid drum developing system.

With regard to the processing of reversal film by individual amateurs, most of the manufacturers state that while the methods outlined above will work with their products, they do not recommend individual processing, as an individual is rarely equipped to exercise the same exact control of all operations that the regular processing stations do. If an individual feels it is necessary to process his own film, the manufacturers point out that far more satisfactory results can be obtained by developing the film (reversal or otherwise) as a *negative* and subsequently making prints from it.

MOTION PICTURE DEVELOPER

(Negative or Positive Film)

	Avoirdupois		*Metric*
Water (about 125° F.) (52° C.)	64	ounces	2.0 liters
Elon	17	grains	1.2 grams
Sodium sulphite (E. K. Co.)	5¼	ounces	160.0 grams
Hydroquinone	350	grains	24.0 grams
Sodium carbonate (E. K. Co.)	2½	ounces	75.0 grams
Potassium bromide	50	grains	3.6 grams
Citric acid	40	grains	2.8 grams
Potassium metabisulphate	85	grains	6.0 grams
Cold water to make	1	gallon	4.0 liters

Average time of development 7 to 15 minutes at 65° F. (18° C.)

Fine Grain Developers for Motion Picture Negative Film

The following formulas have been found to give finer grained images than any other commercially used developer and are recommended for the development of ordinary and panchromatic negative film.

With use, these developers may become slightly muddy but this is due to a suspension of colloidal silver which is likely to form and which is harmless and may be ignored. The tank usually becomes coated with a thin white deposit of silver but this does no harm.

Formula D-76	A		B
Elon	120 grains		160 grains
Sodium Sulphite (E.K.Co.)	14 ounces		14 ounces
Hydroquinone	300 grains		160 grains
Borax	120 grains		120 grains
Water	128 ounces	1 Gallon	128 ounces

Temperature of developer 65° F.

"A" developer will give a little more snap in quality—while the "B" developer will give a softer quality negative.

Directions for Mixing: Owing to the high concentration of sulphite in the formulas, it is somewhat difficult to dissolve all the chemicals unless directions are followed carefully.

First dissolve the Elon in a small volume of water (about 125° F.) and add the solution to the tank. Then dissolve approximately one quarter of the sulphite separately in hot water (about 160° F.) and add the hydroquinone with stirring until completely dissolved. Add this solution to the tank. Then dissolve the remainder of the sulphite in hot water (about 160° F.) add the borax, and when dissolved pour the entire solution into the tank and dilute to the required volume with cold water.

The development time varies with the number of feet which have been processed but the average time for a fresh bath is from 10 to 15 minutes at 65° F. If a slower working developer is required the quantity of Elon, hydroquinone and borax should be reduced. To obtain a faster working developer, increase the quantities of these chemicals.

The life of the developers is practically the same as that of the usual Elon-pyro motion picture developer in general use. An idea of the increase in development time with use may be gained from the fact that after 25,000 feet of film have been processed per 300 gallons of developer the development time is practically doubled.

The developers may be revived once or twice during their life by the addition of half the quantity of borax originally used in the formula.

These developers are somewhat sensitive to the effect of sodium bromide produced by the conversion of the silver bromide in the processed film to metallic silver. A comparatively fresh solution is therefore necessary for developing extreme underexposures. With average studio exposures, however, excellent negatives can be obtained even with the partially exhausted developer.

MOTION PICTURE FIXING BATH

	Avoirdupois	Metric
Water	1 gallon	4.0 liters
Hypo	2 pounds	960.0 grams

When thoroughly dissolved, add the following cool hardener solution slowly stirring to the cool hypo solution.

	Avoirdupois	Metric
Water	4 ounces	128.0 cc.
Sodium sulphite (E. K. Co.)	175 grains	12.0 grams
*Acetic acid (28% pure) (E. K. Co.)	2¼ ounces	72.0 cc.
Powdered potassium alum	350 grains	24.0 grams

*To make 28% acetic acid from glacial acetic acid, dilute three parts of glacial acid with eight parts of water.

To make up the hardener dissolve the chemicals in the order given above. The sodium sulphite should be dissolved completely before adding the acetic acid. After the sulphite acid solution has been mixed thoroughly, add the potassium alum with constant stirring. If the hypo is not thoroughly dissolved before adding the hardener a precipitate of sulphur is likely to form.

FINE GRAIN NEGATIVE DEVELOPER

For Motion Pictures

(Elon-Hydroquinone-Borax)

	Avoirdupois	Metric
Elon	115 grains	8.0 grams
Sodium sulphite (E. K. Co.)	13¼ ounces	400.0 grams
Hydroquinone	290 grains	20.0 grams
Borax	115 grains	8.0 grams
Water to make	1 gallon	4.0 liters

Directions for Mixing: Dissolve the elon in a small volume of water (at about 125° F.) (52° C.) and add the solution to the tank. Then dissolve approximately one-quarter of the sulphite separately in hot water (at about 160° F.) (71° C.), add the hydroquinone with stirring until completely dissolved. Then add this solution to the tank. Now dissolve the remainder of the sulphite in hot water (about 160° F.) (71° C.), add the borax and when dissolved, pour the entire solution into the tank. Dilute to the required volume with cold water.

Time of development is 10 to 20 minutes at 65° F. (18° C.)

NEGATIVE MOTION PICTURE DEVELOPER

(Elon-Hydroquinone)

	Avoirdupois	Metric
Elon	115 grains	8.0 grams
Sodium sulphite (E. K. Co.)	2½ ounces	75.0 grams
Hydroquinone	29 grains	2.0 grams
Sodium carbonate (E. K. Co.)	1¾ ounces	50.0 grams
Potassium bromide	43 grains	3.0 grams
Water to make	1 gallon	4.0 liters

Time of development 6 to 12 minutes at 65° F. (18° C.)

MOTION PICTURE DEVELOPER

Negative or Positive

GLYCIN

(Hubl's Formula)

STOCK SOLUTION

Hot Water	1 gallon
Sodium Sulphite	5 lbs.
DISSOLVE AND ADD:	
Glycin	2 lbs.
DISSOLVE AND ADD SLOWLY:	
Potassium Carbonate	10 lbs.

For Use:

AS A NEGATIVE DEVELOPER: Use 1 part of the Stock Solution to 60 of water.

AS A POSITIVE DEVELOPER: Use 1 part of the Stock Solution to 15 or 30 of water.

POSITIVE DEVELOPER

Elon	7 ounces
Sodium Sulphite	30 lbs.
Hydroquinone	4 lbs.
Potassium Metabisulphite	1 lb.
Sodium Carbonate	15 lbs.
Potassium Bromide	10 ounces
Water to	150 gallons

Time of Development:

For normal contrast, 3½ to 4 minutes at 65°F.

INTENSIFIERS.

SILVER CYANIDE INTENSIFIER.

Especially suited for cartoon and title work where extreme contrast is desired.

Solution A.

Potassium Bromide	1 lb.
Bichloride of Mercury	1 lb.
Water	10 gallons

Solution B.

Pure Cyanide of Potassium	1 lb.
Nitrate of Silver	1 lb.
Water	10 gallons

Place the film in Solution A until the image has been bleached clear through to the back of the film, then rinse well and transfer to Solution B. One immersion gives a heavy degree of intensification, but if a greater degree is required, the operation may be repeated.

BOTH SOLUTIONS ARE HIGHLY POISONOUS.

MERCURIC IODIDE INTENSIFIER.

This formula has the faculty of reducing contrasts in addition to intensifying the general image. HIGHLY POISONOUS.

Water	100 gallons.
Sodium Sulphite (anhydrous)	83 lbs.
Iodide of mercury	8¼ lbs.

Immerse the film in this solution until the desired strength has been obtained. Then wash in running water for at least 15 minutes, place in the regular developer for 3 to 5 minutes. Then wash again for 30 minutes.

REDUCERS.

PERSULPHATE REDUCER.

Reduces the dense portions of negatives without materially changing the high-lights or thinner portions of the image.

Place film (wet) in solution No. 1:

Ammonium Persulphate	33¼ lbs.
Water	100 gallons.

As soon as the right density has been obtained, place the film in the stop-bath, solution No. 2:

Sodium Sulphite	10 lbs.
Water	100 gallons.

After this the film should be washed in running water for 15 to 20 minutes, then dried as usual.

FERRICHLORIDE REDUCER.

Reduces high-lights faster than shadows, thereby overcoming extreme contrast.

Ferrichloride	1 dr.
Hydrochloric Acid	.2 dr.
Water	10. ounces

Negative to be reduced must first be washed until all trace of hypo is removed. Then immerse in the reducer for a minute or so; on removal from this bath no action will be apparent, but on immersing the film in a freshly mixed hypo bath, reduction will take place very quickly. The operation should be watched carefully, and stopped a little short of completion, when the negative should be washed and dried as usual.

FERRICYANIDE (FARMER'S) REDUCER.

Reduces the shadows more than the high-lights. Must be freshly prepared as it deteriorates rapidly.

Add to the desired quantity of *fresh* hypo solution enough of a saturated solution of Potassium Ferricyanide to make it lemon colored. If the color is too deep, verging on orange, reduction will be too rapid to be controlled. When reduction has proceeded far enough, wash the film quickly to prevent further action.

HANDY EMERGENCY WEIGHTS

Dime	40 grs.
Cent	50 grs.
Nickel	80 grs.
Quarter-Dollar	100 grs.
Half-Dollar	200 grs.
Dollar	400 grs.

FLAT BLACK VARNISH FOR BLACKING INSIDE OF CAMERA, ETC.

Alcohol	8 ounces.
Lamp Black	2 ounces.
Shellac	1 ounce.

Dissolve shellac in alcohol, then add lamp black, and mix thoroughly.

FLAT BLACK FOR METALLIC PARTS—SHUTTERS, DIAPHRAGMS, Etc

Nitric Acid	4 ounces.
Copper Wire	¼ ounce.

Dissolve the copper wire in the nitric acid and then add slowly 1¼ ounces of water.

The parts to be blackened must be thoroughly cleaned, then heated and immersed in the acid bath after which they are taken out and brushed off or until the article shows a rich blue-black.

INK FOR WRITING ON GLASS

WHITE: Mix 1 part Chinese White (water-color pigment) or Barium Sulphate with 3 or 4 parts Sodium Silicate Solution (water glass). The sodium silicate solution should have the consistency of glycerin.

BLACK: Mix 1 part liquid Chinese Ink (or Higgins "Eternal" or other carbon ink) with 2 parts Sodium Silicate Solution.

Apply with ordinary steel pen. Ink will dry in 15 minutes. It is waterproof, but may be removed by scraping with a knife.

DEAD BLACK FOR WOOD

Borax	30	grs.	8 grams.
Glycerin	30	minims	8 cc.
Shellac	60	grs.	16 grams.
Water	8	ounces	1000 cc.

Boil till dissolved, and add:

Nigrosine, W. S.	60	grs.	16 grams.

Or paint the wood first with:

Cupric Chloride	75	grs.	75 grams.
Potassium Bichromate	75	ounces	75 grams.
Water	2¼	grs.	1000 cc.

As soon as the surface dries, apply:

Aniline Hydrochlorate	150	grs.	150 grams.
Water	2¼	ounces	1000 cc.

Wipe off any yellow powder that forms. Repeat the process until black enough. Then rub over with boiled linseed oil.

WATERPROOFING WOOD

Asphalt	4	ounces	400 grams.
Pure Rubber	30	grs.	6 grams.
Mineral Naphtha	10	ounces	1000 cc.

Apply with a stiff brush. Give three successive coats, allowing each to dry thoroughly. The vapor from this solution is highly inflammable.

POLISH FOR CAMERAS, WOODWORK, ETC.

Linseed Oil	20	ounces	400	cc.
Spirits of Camphor	2	ounces	40	cc.
Vinegar	4	ounces	80	cc.
Butter of Antimony	1	ounce	20	grams.
Liquid Ammonia	¼	ounce	5	cc.
Water	¼	ounce	5	cc.

Apply very sparingly with a bit of old flannel, and rub off thoroughly with soft rags.

BLACKENING BRASS WORK.

A. Copper Nitrate	200	grs.	450	grams.
Water	1	ounce	1000	cc.
B. Silver Nitrate	200	grs.	450	grams.
Water	1	ounce	1000	cc.

Mix A and B, and place the brass work (perfectly cleaned) in the solution for a few moments, heating on removal.

VARNISH FOR BRASS WORK

Celluloid	10	grs.	4	grams.
Amyl Alcohol	½	ounce	100	cc.
Acetone	½	ounce	100	cc.

Commercial "cold lacquer" may also be used for this purpose.

TO BLACKEN ALUMINUM

Clean thoroughly with fine emery powder, wash well, and immerse in:

Ferrous Sulphate	1	ounce	80	grams.
White Arsenic	1	ounce	80	grams.
Hydrochloric Acid	12	ounces	1000	cc.

Dissolve and add:

Water	12	ounces	1000	cc.

When the color is deep enough, dry off with fine sawdust, and lacquer.

SILVERING MIRRORS.

A. Silver Nitrate	175	grs.	40	grams.
Distilled Water	10	ounces	1000	cc.
B. Ammonium Nitrate	262	grs.	60	grams.
Distilled Water	10	ounces	1000	cc.
C. Pure Caustic Potash	1	ounce	100	grams.
Distilled Water	10	ounces	1000	cc.
D. Pure Sugar Candy	½	ounce (avoirdupois)	100	grams.
Distilled Water	5	ounces	1000	cc.

Dissolve and add:

Tartaric Acid	50	grs.	23	grams.

Boil in flash for 10 minutes, and when cool add:

Alcohol	1	ounce	200	cc.

For use, take equal parts of A and B. Mix together also equal parts of C and D—mixing in another measure. Then mix both of these two mixtures together in the silvering vessel, and suspend the mirror *face downward* in the solution.

THERMOMETRIC TABLES

For converting temperature readings by one system into those of any other system, these rules will be found useful.

Centigrade (Celsius) to Fahrenheit:

Multiply degrees C. by 9, divide by 5, then add 32.

Centigrade to Réaumur:

Multiply degrees C. by 4 and divide by 5.

Fahrenheit to Centegrade (Celsius):

Subtract 32 from Fahrenheit reading; multiply by 5 and divide by 9.

Fahrenheit to Réaumur:

Subtract 32, divide by 9, multiply by 4.

Réaumur to Centigrade (Celsius):

Multiply by 5 and divide by 4.

Réaumur to Fahrenheit:

Multiply by 9, divide by 4, add 32.

KODACOLOR FINISHING STATIONS

KODACOLOR films should be developed as promptly as possible after being exposed in order to secure the very best results. So users of kodacolor may have the most prompt service possible, the Eastman Kodak Company has established finishing stations in all parts of the world where kodacolor film may be processed. The following is the list of these stations at publication date of this book. This list is published for the benefit of the readers of this volume who may wish kodacolor service while traveling.

United States

Chicago, Ill., Eastman Kodak Company, 18th Street and Indiana Ave.
Jacksonville, Fla., Cine-Kodak Service, Inc., 315 West 8th St.
Kansas City, Mo., Cine-Kodak Service, Inc., 422 East 10th St.
Rochester, N. Y., Eastman Kodak Company.
San Francisco, Calif., Eastman Kodak Company, 241 Battery St.

Canada

Toronto, Ont., Canadian Kodak Co., Ltd., Toronto 9.

Europe

Belgium: Brussels, Kodak Limited, Rue Neuve 88.
Denmark, Copenhagen, Kodak Aktieselskab, Vodroffsvj 26.
England, London, Kodak Limited, Kingsway, W. C. 2.
France, Paris, Kodak-Pathe, Place Vendome 28; Avenue des Champs Elysees 63.
Germany, Berlin, Kodak Aktiengesellschaft, Liepzeiger Strasse 114.
Italy, Milan, Kodak Societa Anomina, Corso Vittorio Emanuele 34.
Netherlands, The Hague, Kodak Limited, Noordeinde 10.
Norway, Oslo, J. L. Nerlien, A. S., Nedre Slotsgate 13.
Spain, Madrid, Kodak Sociedad Anomina, Puerta del Sol 4.
Sweden, Gothenberg, Hasselblads Fotogr. A. B., Ostra Hamngatan 41-43.
Switzerland, Lausanne, Kodak Societe Anonyme, Avenue Jean Jacques Mercier 13.

Philippine Islands

Manila, Kodak Philippines, Limited, Calle David 181.

Dutch East Indies

Java, Batavia, Kodak Limited, Noordwijk 38, Weltvreden.

Australasia

Australia, Melbourne, Kodak Australasia Pty., Ltd., 284 Collins St.

Hawaiian Islands

Honolulu, Kodak Hawaii, Ltd., 817 Alakea St.

Cuba

Havana, Kodak Cubana, Ltd., Zenea 236.

South America

Argentina, Buenos Aires, Kodak Argentina, Ltd., Calle Paso 438.
Brazil, Rio de Janeiro, Kodak Brasileira, Ltd., Rua Sao Pedro 270.
Chile, Santiago, Kodak Chilena, Ltd., Delicias 1472.
Peru, Lima, Kodak Peruana, Ltd., Divorciadas 650.

Republic of Panama

Panama City, Kodak Panama, Ltd., Edificio Grebmar, Ave. Pablo Arosemena.

Mexico

Mexico City, Kodak Mexicana, Ltd., Independencia 37.

Africa

South Africa, Cape Town, Kodak (S. A.), Limited, 38 Adderly St.

Asia

China, Shanghai, Eastman Kodak Company, 24 Yuen Ming Yuen Road.
India, Calcutta, Kodak, Limited, 17 Park Street.
Japan, Osaka, Cine-Kodak Service Japan, Inc., 1 Dojima Bldg.
Straits Settlement, Singapore, Kodak, Limited, 8 Battery Road.

Picture Sizes Obtained with Projection Lenses

Focal Length of Lens in Inches	Distance in Feet From Screen													
	8	10	12	16	20	25	32	36	40	45	50	64	75	100
	Size of Picture (Feet and Decimals) (First figure shows width, second figure shows height)													
¾	4.10 3.04	5.13 3.80												
1	3.08 2.28	3.85 2.85	4.62 3.42	6.16 4.56	7.70 5.70	9.63 7.13								
1½	2.05 1.52	2.57 1.90	3.08 2.28	4.11 3.04	5.13 3.80	6.42 4.75	8.21 6.03	9.24 6.84						
2	1.54 1.14	1.93 1.43	2.31 1.71	3.08 2.28	3.85 2.85	4.81 3.56	6.16 4.56	6.93 5.13	7.70 5.70	8.65 6.41	9.63 7.13			
2½	1.23 .91	1.54 1.14	1.85 1.37	2.46 1.83	3.08 2.28	3.85 2.85	4.93 3.65	5.54 4.10	6.16 4.56	6.93 5.13	7.70 5.70	9.86 7.30		
3		1.28 .95	1.54 1.14	2.05 1.52	2.57 1.90	3.21 2.38	4.11 3.04	4.62 3.42	5.13 3.80	5.77 4.28	6.42 4.75	8.21 6.08	9.63 7.13	
3½		1.10 .81	1.32 .98	1.76 1.30	2.20 1.63	2.75 2.04	3.52 2.60	3.96 2.93	4.40 3.26	4.95 3.66	5.50 4.07	7.04 5.21	8.25 6.11	11.00 8.14
4			1.16 .86	1.34 1.14	1.94 1.43	2.41 1.73	3.00 2.28	3.47 2.57	3.85 2.85	4.35 3.21	4.82 3.57	6.16 4.56	7.22 5.35	9.63 7.13

Table of Hyperfocal Distances

FOLLOWING will be found a table of hyperfocal distances, showing the distance at which critical sharpness is obtained for each diaphragm opening when the lens is focused at infinity. All objects at the distances shown and beyond will be in focus. You will notice that the telephoto lens is not scaled clear up to the infinity mark. For subjects between the highest footage mark on lens focusing scale and the hyperfocal distance for diaphragm stop being used, your estimate of proper setting between highest footage on lens and infinity mark will give sharp focusing.

Focal Length	F1.8	F2.7	F3.3	F3.5	F4	F4.5	F5.5	F6.3	F8	F11	F16	F22	F32
25 m/m	22′	15′	12′	11½′	10′	9′	7′	6′	5′	4′	2½′		
35 m/m	44′	29′	24′	22½′	20′	17½′	14½′	12½′	10′	7′	5′		
3″		139′	114′	107′	94′	83′	68′	60′	47′	34′	23′	17′	12′
Telephoto 3¾″			178′	167′	146′	130′	107′	93′	73′	53′	36′	26′	18′
Telephoto 4″				190′	167′	148′	121′	106′	83′	61′	42′	30′	21′
Telephoto 6″					375′	333′	273′	238′	188′	136′	94′	68′	47′

Exposure Guide for Ciné-Kodak, Model BB, with *f*.1.9 Lens (Black and White Pictures Only)

(These figures, except as noted, apply only when the camera is operated at full, or normal speed.)

SUBJECT	TIME	Bright—No Clouds Over Sun	Light Clouds Over Sun	Cloudy Dull
		Diaphragm	Diaphragm	Diaphragm
A. Sea, Sky, Beach and Snow Scenes Distant Landscapes, Mountains	Apr.-Sept.	*f*.16	*f*.11	*f*.8
	Oct.-March	*f*.11	*f*.8	*f*.5.6
B. Close-ups* of Group A Open Landscapes, Games, etc., with no heavy shade	Apr.-Sept.	*f*.11	*f*.8	*f*.5.6
	Oct.-March	*f*.8	*f*.5.6	*f*.4
C. Close-ups* of Group B Street Scenes. Groups where houses or trees obstruct part of the light from the sky	Apr.-Sept.	*f*.8	*f*.5.6	*f*.4
	Oct.-March	*f*.5.6	*f*.4	*f*.2.8
D. Close-ups* of Group C Scenes on shady side of streets Boating scenes out of direct sunlight	Apr.-Sept.	*f*.5.6	*f*.4	*f*.2.8
	Oct.-March	*f*.4	*f*.2.8	*f*.1.9
E. Close-ups* of Group D Scenes on heavily shaded streets Scenes on heavily shaded porches	Apr.-Sept.	*f*.4	*f*.2.8	*f*.1.9
	Oct.-March	*f*.2.8	*f*.1.9	*f*.1.9 half-speed

*The term "close-up" means pictures taken from 2 feet to 6 feet from the lens. Figures above are for the hours from two hours after sunrise until two hours before sunset. To make pictures earlier or later, use the next larger diaphragm opening. The above figures apply to the temperate zone; for exposures in the tropics, see the manual.

These rules do not apply to Kodacolor—home movies in full color. Kodacolor pictures must be made with the diaphragm set at *f*.1.9, and the Kodacolor Filter in position before the lens (see folder).

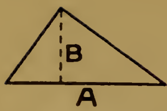
The above table can be used with the *f*.4.5 Long Focus Lens by substituting "*f*.4.5" wherever "*f*.4" appears, and "Too dark" wherever "*f*.2.8" or "*f*.1.9" appears. For "close-ups," subjects must not be nearer than 6 feet from the *f*.4.5 Long Focus Lens.

Use the *half speed*, see page 11, with the largest diaphragm opening in position, when the light conditions are unfavorable for making exposures at *normal* speed, as on *very dark and rainy days;* also for exposures earlier and later than the hours given above, when an opening larger than the largest one of the lens would be required.

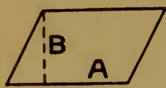
The Projected Field for Filmo *Camera Lenses, showing Approximate Picture Areas Obtained*

Lenses Focal Length	Distance From Camera (Feet)																								
	Plane	Angle	1	1½	2	3	4	5	6	7	8	15	25	30	40	50	60	75	100	150	200	300	400	500	1000
20 m/m	Horizontal	26°-4′	.49	.73	.98	1.5	2.0	2.4	2.9	3.4	3.9	7.3	12.2	14.7	19.5	24.4	29.3	36.7	48.9	73.3	97.8	146.7	195.6	244.5	489.
	Vertical	19°-54′	.36	.54	.72	1.1	1.4	1.8	2.2	2.5	2.9	5.4	9.	10.9	14.5	18.1	21.7	27.1	36.2	54.3	72.4	108.6	144.8	181.	362.
25 m/m	Horizontal	21°-22′	.39	.59	.78	1.2	1.6	2.0	2.3	2.7	3.1	5.9	9.7	11.7	15.6	19.5	23.5	29.3	39.1	58.7	78.2	117.3	156.5	195.6	391.2
	Vertical	16°-9′	.29	.43	58	.87	1.2	1.4	1.7	2.0	2.3	4.3	7.2	8.7	11.6	14.5	17.4	21.7	28.9	43.4	57.9	86.9	115.8	144.8	289.6
35 m/m	Horizontal	15°-37′	.28	.42	.56	.84	1.1	1.4	1.7	1.9	2.2	4.2	6.9	8.4	11.2	13.9	16.8	20.9	27.9	41.9	55.8	83.8	111.7	139.7	279.4
	Vertical	11°-41′	.21	.31	.41	.62	.83	1.0	1.2	1.4	1.6	3.1	5.1	6.2	8.3	10.3	12.4	15.5	20.7	31.	41.3	62.	82.7	103.4	206.8
50 m/m	Horizontal	11°-4′	.19	.29	.39	.59	.78	.98	1.2	1.4	1.6	2.9	4.8	5.9	7.8	9.8	11.7	14.6	19.5	29.3	39.1	58.7	78.2	97.8	195.6
	Vertical	8°-14′	.14	.22	.29	.43	.58	.72	.87	1.0	1.1	2.2	3.6	4.3	5.8	7.2	8.7	10.8	14.5	21.7	28.9	43.4	57.9	72.4	144.8
3″	Horizontal	7°-20′	.13	.19	.26	.38	.51	.64	.77	.90	1.0	1.9	3.2	3.8	5.1	6.4	7.7	9.6	12.8	19.2	25.7	38.5	51.3	64.2	128.6
	Vertical	5°-26′	09	.14	.19	.28	.38	.47	.57	.66	.76	1.4	2.4	2.8	3.8	4.7	5.7	7.1	9.5	14.2	19.0	28.5	38.0	47.6	95.0
3¾″	Horizontal	5°-52′	.10	.15	.21	.31	.41	.51	.62	.72	.82	1.5	2.6	3.1	4.1	5.1	6.2	7.7	10.3	15.4	20.5	30.8	41.1	51.4	102.7
	Vertical	4°-21′	.07	.11	.15	.23	.30	.38	.46	.51	.61	1.1	1.9	2.3	3.0	3.8	4.6	5.7	7.6	11.4	15.2	22.8	30.4	38.0	76.0
4″	Horizontal	5°-30′	.10	.14	.19	.29	.38	.48	.58	.67	.77	1.4	2.4	2.9	3.8	4.8	5.8	7.2	9.6	14.4	19.2	28.9	38.5	48.1	96.2
	Vertical	4°-5′	07	.11	.14	.21	.28	.36	.43	.50	.57	1.1	1.8	2.1	2.8	3.5	4.3	5.3	7.1	10.7	14.2	21.3	28.5	35.6	71.2
6″	Horizontal	3°-40	.06	.09	.13	.19	.26	.32	.38	.45	.51	.96	1.6	1.9	2.5	3.2	3.8	4.8	6.4	9.6	12.8	19.2	25.7	32.	64.1
	Vertical	2°-43′	.05	07	.09	.14	.19	.24	.28	.33	.38	.71	1.2	1.4	1.9	2.4	2.8	3.5	4.7	7.1	9.5	14.2	19.	23.7	47.5

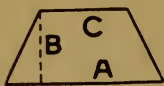
Mensuration



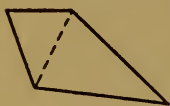
Area of triangle = base $\times \frac{1}{2}$ altitude
$= A \times \frac{1}{2} B$



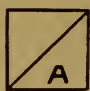
Area parallelogram = base $\times$ altitude
$= A \times B$



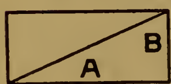
Area of trapezoid = $\frac{1}{2}$ (sum of parallel sides) $\times$ altitude = $\frac{1}{2}(A + C) \times B$



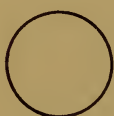
Area of trapezium = Divide into triangles and find area of each separately



Diagonal of a square = the square root of twice the square of one side = 1.414 A

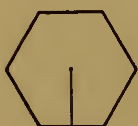


Diagonal of a rectangle = the square root of the sum of the squares of the adjacent sides
$= \sqrt{A^2 + B^2}$



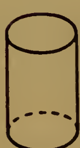
Circumference of a circle
= Diameter $\times$ 3.1416
= 2 $\times$ radius $\times$ 3.1416

Area of a circle
= The square of the radius $\times$ 3.1416
= the square of the diameter $\times$ .7854



A regular polygon, one whose sides and angles are all equal, area = $\frac{1}{2}$ sum of the sides $\times$ perpendicular from the center to one of the sides

The surface of a sphere = 4 $\times$ radius squared $\times$ 3.1416
Contents of a sphere = 4/3 $\times$ radius cubed $\times$ 3.1416



Surface of a cylinder = area of both ends + length $\times$ circumference
Contents of a cylinder = area of one end $\times$ length

Surface of a cone = area of base + circumference of base × ½ the slant height
Contents of a cone = area of base × ⅓ altitude

To square a number multiply it by itself. To cube a number multiply it by itself and multiply the result by the number.

Useful Information

Troy Weight

24 grains = 1 pennyweight (dwt.) 12 ounces = 1 pound
20 dwts. = 1 ounce
Used for weighing gold, silver and jewels

Apothecaries' Weight

20 grains = 1 scruple 8 drams = 1 ounce
3 scruples = 1 dram 12 ounces = 1 pound
The ounce and pound in this are the same as in Troy weight

Avoirdupois Weight

27 11/32 grains = 1 dram 4 quarters = 1 cwt.
16 drams = 1 ounce 2,000 lbs. = 1 short ton
16 ounces = 1 pound 2,240 lbs. = 1 long ton
25 pounds = 1 quarter

Dry Measure

2 pints = 1 quart 4 pecks = 1 bushel
8 quarts = 1 peck 36 bushels = 1 chaldron

Liquid Measure

4 gills = 1 pint 31½ gallons = barrel
2 pints = 1 quart 2 barrels = hogshead
4 quarts = 1 gallon 16 fluid ounces = 1 pint

Time Measure

60 seconds = 1 minute 24 hours = 1 day
60 minutes = 1 hour 7 days = 1 week
28, 29, 30 or 31 days = 1 calendar month (30 days = 1 month in computing interest)
365 days = 1 year 366 days = 1 leap year

Long Measure

12 inches = 1 foot 40 rods = 1 furlong
3 feet = 1 yard 8 furlongs = 1 sta. mile
5½ yards = 1 rod 3 miles = 1 league
5280 ft. = 1 mile

Cloth Measure

2¼ inches = 1 nail 4 quarters = 1 yard
4 nails = 1 quarter

Square Measure

144 sq. inches = 1 sq. ft.
9 sq. ft. = 1 sq. yard
30¼ sq. yards = 1 sq. rod
40 sq. rods = 1 rood
4 roods = 1 acre
640 acres = 1 sq. mile
43560 sq. ft. = 1 acre

Surveyors' Measure

7.92 inches = 1 link
4 rods = 1 chain
25 links = 1 rod
10 sq. chains or 160 sq. rods = 1 acre
640 acres = 1 sq. mile
36 sq. miles (6 miles square) = 1 township

Cubic Measure

1,728 cubic in. = 1 cu. ft.
128 cu. ft. = 1 cord (wood)
27 cubic ft. = 1 cubic yard
40 cu. ft. = 1 ton (shpg.)
2,150.42 cubic inches = 1 standard bushel
231 cubic inches = 1 standard gallon (liquid)
1 cubic foot = 4/5 of a bushel

To find diameter of a circle multiply circumference by .31831.

To find circumference of a circle multiply diameter by 3.1416.

To find area of a circle multiply square of diameter by .7854.

To find surface of a ball multiply square of diameter by 3.1416.

To find side of an equal square multiply diameter by .8862.

To find cubic inches in a ball multiply cube of diameter by .5236.

A gallon of water (U S Standard) weighs 8⅓ lbs. and contains 231 cubic inches.

A cubic foot of water contains 7½ gallons, 1728 cubic inches, and weighs 62½ lbs.

Intrinsic Brightness of Light Sources

Light Source	*Candle Power per Sq. M/M*
High Intensity White Flame Carbon Arc, Forced	1200
Pure Carbon Arc at 22 atmospheres (*about*)	1000
Sun at Zenith	920
High Intensity White Flame Carbon Arc, as usually operated	690
Positive Crater of Tantalum Arc (*about*)	500
Positive Crater of Solid Carbon Arc, on D.C.	180
Positive Crater of Cored Carbon Arc, on D.C.	130
Yellow Arc Stream	8.0
Magnetite Arc Stream	6.2
Mercury Vapor Tube	0.023
Moore Carbon Dioxide Tube	0.009

Electrical Energy

The power that is transmitted by any electric circuit depends on the current and the voltage. The unit, the watt, is the amount of power obtained from one ampere at one volt. This unit is too small for ordinary purposes and the kilowatt equal to 1000 watts is used.

For D. C. circuits:

$$W = I \times E$$

W = Power in watts
I = Current in amperes
E = Electromotive force in volts

In A. C. circuits the entire current is not always available for doing work. This calls for another term in the energy equation, the power factor, which is the ratio of the current available for power to the total current. For single-phase A. C. circuits the equation becomes

$$W = I \times E \times P$$

P = Power factor of the circuit

For two-phase A.C.

$$W = 2 \times I \times E \times P$$

For three-phase A.C.

$$W = 1.73 \times I \times E \times P$$

Electrical and Mechanicai Conversion Factors

1 H.P. = 746 watts = .746 kw.
1 kw. = 1.344 H.P. = approx. 1⅓ H.P.

Electricity

Ohmic Resistance

The resistance of a uniform electric conductor at 0°, Centigrade, is given by the formula:

$$R \text{ (in ohms)} = p\,L/A$$

L = length of conductor in inches
A = Cross-section in square inches
p = Resistivity of conductor at 0° C., values of which are given in the following table

Table of Resistivities

(Resistivity is the resistance in ohms between any two opposite faces of a 1 inch cube of the material. It is given in microhms or millionths of an ohm.)*

Metal	*Resistivity at 0° C. (in microhms)*
Aluminum (annealed)	1.14
Aluminum (commercial)	1.05
Aluminum bronze	4.96
Bismuth (compressed)	51.2
Brass	2.82
Copper (drawn)	0.637
Copper (annealed)	0.625
German silver	8.23
Gold (annealed)	0.803
Iron (wrought)	3.82
Lead (compressed)	7.68
Magnesium	1.72
Mercury	37.1
Nickel (annealed)	4.89
Platinum (annealed)	3.53
Silver (annealed)	0.575
Tin	5.16
Tungsten	2.
Zinc (pressed)	2.28

* This definition applies to English units and to the numerical values given in the table. In general, resistivity is the resistance of a unit cube. The resistance of a conductor at any temperature is

$$R_2 = R_1 \frac{(1 + at_2)}{(1 + at_1)}$$

in which

R_1 = known resistance at a temperature t_1 degrees Centigrade
R_2 = required resistance at a temperature t_2 degrees Centigrade
a = temperature coefficient of electrical resistance, the value of which is given for different metals in the following table.

Thermometer Scales

There are two thermometer scales in general use in this country at the present time, the Fahrenheit and the Centigrade. On the Fahrenheit scale the melting point of ice is 32° and the boiling point of water at sea-level is 212°. On the Centigrade scale 0° is the melting point of ice and 100° the boiling point of water. Another scale, the Absolute, is sometimes used. This takes its zero at a point assumed to be the lowest temperature that can exist. This point was calculated from the contraction of gases when cooled and found to be —273° C, i. e., 273° below zero Centigrade. The size of the degrees of the Centigrade and Absolute scales is the same, so to convert degrees Centigrade to Absolute all that is necessary is to add 273.

To convert degrees Centigrade to Fahrenheit multiply by 1.8 and add 32.

To convert degrees Fahrenheit to Centigrade, subtract 32 and divide the result by 1.8. Care should be taken that the sign of the result is correct when the temperature is below the freezing point of water.

(The constant 1.8 is obtained as follows: Between the freezing and boiling points of water there are 100° C and 212°—32° = 180° F. Therefore, 1° C = 1.8° F. The factor 32 arises from the fact that 0° C corresponds to 32° F.)

Temperature Coefficients of Electrical Resistance

Metal	*Temperature Coefficient (approximately) for 1° C.*
Aluminium (commercial)	0.00435
Copper (annealed)	0.00400
German silver	0.00036
Gold (annealed)	0.00365
Iron (wrought)	0.00463
Mercury	0.00072
Platinum	0.00247
Silver	0.00377
Tungsten	0.00570
Zinc (pressed)	0.00365

Note. The temperature coefficient of a material is its increase in resistance for each degree Centigrade rise in temperature, and it is expressed as a decimal fraction of the resistance at 0° C.

Decimal Equivalents of Fractions and Equivalents of Fractions of an Inch in Mm.

1/8	1/16	1/32	1/64	1/128	mm.	Decim. of an inch	1/8	1/16	1/32	1/64	1/128	mm.	Decim. of an inch
..	..	..	...	1	.198	.0078125	..	..	..	...	65	12.898	.5078125
..	..	..	1	2	.397	.0156250	..	..	..	33	66	13.097	.515625
..	..	..	...	3	.595	.0234375	..	..	..	...	67	13.295	.5234375
..	..	1	2	4	.794	.031250	..	..	17	34	68	13.494	.531250
..	..	..	...	5	.992	.0390625	..	..	..	...	69	13.692	.5390625
..	..	..	3	6	1.191	.046875	..	..	..	35	70	13.891	.546875
..	..	..	...	7	1.389	.0546875	..	..	..	...	71	14.089	.5546875
..	1	2	4	8	1.588	.062500	..	9	18	36	72	14.288	.562500
..	..	..	...	9	1.786	.0703125	..	..	..	...	73	14.486	.5703125
..	..	..	5	10	1.984	.078125	..	..	..	37	74	14.684	.578125
..	..	..	...	11	2.183	.0859375	..	..	..	...	75	14.883	.5859375
..	..	3	6	12	2.381	.093750	..	..	19	38	76	15.081	.593750
..	..	..	...	13	2.580	.1015625	..	..	..	...	77	15.280	.6015625
..	..	..	7	14	2.778	.109375	..	..	..	39	78	15.478	.609375
..	..	..	...	15	2.977	.1171875	..	..	..	...	79	15.677	.6171875
1	2	4	8	16	3.175	.125000	5	10	20	40	80	15.875	.625000
..	..	..	...	17	3.373	.1328125	..	..	..	...	81	16.073	.6328125
..	..	..	9	18	3.572	.140625	..	..	..	41	82	16.272	.640625
..	..	..	...	19	3.770	.1484375	..	..	..	...	83	16.470	.6484375
..	..	5	10	20	3.969	.156250	..	..	21	42	84	16.669	.656250
..	..	..	...	21	4.167	.1640625	..	..	..	...	85	16.867	.6640625
..	..	..	11	22	4.366	.171875	..	..	..	43	86	17.066	.671875
..	..	..	...	23	4.564	.1796875	..	..	..	...	87	17.264	.6796875
..	3	6	12	24	4.763	.187500	..	11	22	44	88	17.463	.687500
..	..	..	...	25	4.961	.1953125	..	..	..	...	89	17.661	.6953125
..	..	..	13	26	5.159	.203125	..	..	..	45	90	17.859	.703125
..	..	..	...	27	5.358	.2109375	..	..	..	...	91	18.058	.7109375
..	..	7	14	28	5.556	.218750	..	..	23	46	92	18.256	.718750
..	..	..	...	29	5.755	.2265625	..	..	..	...	93	18.455	.7265625
..	..	..	15	30	5.953	.234375	..	..	..	47	94	18.653	.734375
..	..	..	...	31	6.152	.2421875	..	..	..	...	95	18.852	.7421875
2	4	8	16	32	6.350	.250000	6	12	24	48	96	19.050	.750060
..	..	..	...	33	6.548	.2578125	..	..	..	...	97	19.248	.7578125
..	..	..	17	34	6.747	.265625	..	..	..	49	98	19.447	.765625
..	..	..	...	35	6.945	.2734375	..	..	..	...	99	19.645	.7734375
..	..	9	18	36	7.144	.281250	..	..	25	50	100	19.844	.78125
..	..	..	...	37	7.342	.2890625	..	..	..	...	101	20.042	.7890625
..	..	..	19	38	7.541	.296875	..	..	..	51	102	20.241	.796875
..	..	..	...	39	7.739	.3046875	..	..	..	...	103	20.439	.8046875
..	5	10	20	40	7.938	.312500	..	13	26	52	104	20.638	.8125
..	..	..	...	41	8.136	.3203125	..	..	..	...	105	20.836	.8203125
..	..	..	21	42	8.334	.328125	..	..	..	53	106	21.034	.828125
..	..	..	...	43	8.533	.3359375	..	..	..	...	107	21.233	.8359375
..	..	11	22	44	8.731	.343750	..	..	27	54	108	21.431	.84375
..	..	..	...	45	8.930	.3515625	..	..	..	...	109	21.630	.8515625
..	..	..	23	46	9.128	.359375	..	..	..	55	110	21.828	.859375
..	..	..	...	47	9.327	.3671875	..	..	..	...	111	22.027	.8671875
3	6	12	24	48	9.525	.375000	7	14	28	56	112	22.225	.875000
..	..	..	...	49	9.723	.3828125	..	..	..	...	113	22.423	.8828125
..	..	..	25	50	9.922	.390625	..	..	..	57	114	22.622	.890625
..	..	..	...	51	10.120	.3984375	..	..	..	...	115	22.820	.8984375
..	..	13	26	52	10.319	.406250	..	..	29	58	116	23.019	.906250
..	..	..	...	53	10.517	.4140625	..	..	..	...	117	23.217	.9140625
..	..	..	27	54	10.716	.421875	..	..	..	59	118	23.416	.921875
..	..	..	...	55	10.914	.4296875	..	..	..	...	119	23.614	.9296875
..	7	14	28	56	11.113	.437500	..	15	30	60	120	23.813	.937500
..	..	..	...	57	11.311	.4453125	..	..	..	...	121	24.011	.9453125
..	..	..	29	58	11.509	.453125	..	..	..	61	122	24.209	.953125
..	..	..	...	59	11.708	.4609375	..	..	..	...	123	24.408	.9609375
..	..	15	30	60	11.906	.46875	..	..	31	62	124	24.606	.96875
..	..	..	...	61	12.105	.4765625	..	..	..	...	125	24.805	.9765625
..	..	..	31	62	12.303	.484375	..	..	..	63	126	25.003	.984375
..	..	..	...	63	12.502	.4921875	..	..	..	...	127	25.202	.9921875
4	8	16	32	64	12.700	.500000	8	16	32	64	128	25.400	1.0000000

National High Intensity Projector Combinations

The trims given on this page are suggested by the National Carbon Company as giving best results in the projection of motion pictures.

General Electric Lamps

Arc Amperage		*Size*	*Kind*
50	Positive	9m/m x 20″	Nat'l H. I. White Flame Projector
	Negative	11/32 x 9″	Nat'l Orotip Cored Projector
75	Positive	11m/m x 20″	Nat'l H. I. White Flame Projector
	Negative	⅜ x 9″	Nat'l Orotip Cored Projector
100–120	Positive	13.6m/m x 20″	Nat'l H. I. White Flame Projector
	Negative	7/16 x 9″	Nat'l Orotip Cored Projector

H & C and Sunlight Arc (Sperry) Lamps

Arc Amperage		*Size*	*Kind*
50	Positive	9m/m x 20″	Nat'l H. I. White Flame Projector
	Negative	5/16 x 9″	Nat'l Orotip Cored Projector
75	Positive	11m/m x 20″	Nat'l H. I. White Flame Projector
	Negative	11/32 x 9″	Nat'l Orotip Cored Projector
100–120	Positive	13.6m/m x 20″	Nat'l H. I. White Flame Projector
	Negative	⅜ x 9″	Nat'l Orotip Cored Projector

Ashcraft Lamps

Arc Amperage		*Size*	*Kind*
80	Positive	½ x 12″	Nat'l White Flame Cored
	Negative	⅜ x 9″	Nat'l Orotip Cored Projector
100 to 120	Positive	13.6m/m x 20″	Nat'l H. I. White Flame Projector
	Negative	⅜ x 9″	Nat'l Orotip Cored Projector

Carrying Capacity of Copper Wires

The following table, showing the allowable carrying capacity of copper wires and cables of 98% conductivity, according to the standard adopted by the American Institute of Electrical Engineers, must be followed in placing interior conductors.

For insulated aluminum wire the safe carrying capacity is 84% of that given in the following tables for copper wire with the same kind of insulation.

B. & S. Gauge	*Circular Mills*	*Table A Rubber Insulation Amperes*	*Table B Other Insulations Amperes*
18	1,624	3	5
16	2,583	6	8
14	4,107	12	16
12	6,530	17	23
10	10,380	24	32
8	16,510	33	46
6	26,250	46	65
5	33,100	54	77
4	41,740	65	92
3	52,630	76	110
2	66,370	90	131
1	83,690	107	156
0	105,500	127	185
00	133,100	150	220
000	167,800	177	262
0000	211,600	210	312
	Circular Mils.		
	200,000	200	300
	300,000	270	400
	400,000	330	500
	500,000	390	590
	600,000	450	680
	700,000	500	760
	800,000	550	840
	900,000	600	920
	1,000,000	650	1,000
	1,100,000	690	1,080
	1,200,000	730	1,150
	1,300,000	770	1,220
	1,400,000	810	1,290
	1,500,000	850	1,360
	1,600,000	890	1,430
	1,700,000	930	1,490
	1,800,000	970	1,550
	1,900,000	1,010	1,610
	2,000,000	1,050	1,670

The lower limit is specified for rubber-covered wires to prevent gradual deterioration of the high insulations by the heat of the wires, but not from fear of igniting the insulation. The question of drop is not taken into consideration in the above tables.

Properties of Copper Wire

English System—Brown & Sharpe Gauge

Numbers	*Diameters in mils.*	*Areas in Circular mils. C.M. = d^2*	*Weights 1000 ft. Pounds*	*Resistance per 1000 ft. in International Ohms At 75° F*
0000	460.	211 600.	641.	.049 66
000	410.	168 100.	509.	.062 51
00	365.	133 225.	403.	.078 87
0	325.	105 625.	320.	.099 48
1	289.	83 521.	253.	.125 8
2	258.	66 564.	202.	.157 9
3	229.	52 441.	159.	.200 4
4	204.	41 616.	126.	.252 5
5	182.	33 124.	100.	.317 2
6	162.	26 244.	79.	.400 4
7	144.	20 736.	63.	.506 7
8	128.	16 384.	50.	.641 3
9	114.	12 996.	39.	.808 5
10	102.	10 404.	32.	1.01
11	91.	8 281.	25.	1.269
12	81.	6 561.	20.	1.601
13	72.	5 184.	15.7	2.027
14	64.	4 096.	12.4	2.565
15	57.	3 249.	9.8	3.234
16	51.	2 601.	7.9	4.04
17	45.	2 025.	6.1	5.189
18	40.	1 600.	4.8	6.567
19	36.	1 296.	3.9	8.108
20	32.	1 024.	3.1	10.26
21	28.5	812.3	2.5	12.94
22	25.3	640.1	1.9	16.41
23	22.6	510.8	1.5	20.57
24	20.1	404.	1.2	26.01
25	17.9	320.4	.97	32.79
26	15.9	252.8	.77	41.56
27	14.2	201.6	.61	52.11
28	12.6	158.8	.48	66.18
29	11.3	127.7	.39	82.29
30	10.	100.	.3	105.1
31	8.9	79.2	.24	132.7
32	8.	64.	.19	164.2
33	7.1	50.4	.15	208.4
34	6.3	39.7	.12	264.7
35	5.6	31.4	.095	335.1
36	5.	25.	.076	420.3

METRIC EQUIVALENTS

Length

Cm. = .3937 In.	In. = 2.54 Cm.
Meter = 3.28 Ft.	Ft. = .305 Meter
Meter = 1.09 Yd.	Yd. = .914 Meter
Kilom. = .621 Mile	Mile = 1.61 Kilom.

Area

Sq. Cm.=0.1550 Sq. In.	Sq. In. = 6.452 Sq. Cm.
Sq. M. = 10.764 Sq. F.	Sq. Ft. = .0929 Sq.M.
Sq. M. = 1.196 Sq. Yd.	Sq. Yd. = .836 Sq. M.
Hectare = 2.47 Acres	Acre = 0.405 Hectare
Sq. Kilom = .386 Sq.mi.	Sq. mi.=2.59 Sq. Kilom.

Volume

Cu. Cm. = 0.353 Cu. ft.	Cu.In. = 16.4 Cu. Cm.
Cu. M. = 35.31 Cu. ft.	Cu. Ft. = .028 Cu. M.
Cu. M. = 1.308 Cu. Yd.	Cu. Yd. = .765 Cu. M.

Capacity

Litre = .0353 Cu. Ft.	Cu. Ft. = 28.32 Litres
Litre = .2642 Gal. (U. S.)	Gal. = 3.785 Litres
Litre = 61.023 Cu. In.	Cu. In. = .0164 Litre

Weight

Gram = 15.423 Grains	Grain = .0694 Gram
Gram = .0353 Ounce	Ounce = 28.34 Gram
Kilogram = 2.205 Lb.	Pound = .454 Kilogram
Kilogram = .0011 Ton	Ton = 907.03 Kilogram
Tonne = 1.1025 Ton	Ton = .907 Tonne

Grams per cubic meter = .437 grains per cu. ft.

Grains per cubic foot = 2.288 grams per cubic meter.

Kilograms per cubic meter = .0624 pounds per cubic foot.

Pounds per cubic foot = 16.02 Kilograms per cu. meter.

Pressure

Kilograms per square Cm. = 14.225 pounds per square inch.

Pounds per square inch = .0703 Kilograms per square Cm.

Kilograms per sq. meter = .205 pounds per sq. foot.

Pounds per sq. ft. = 4.88 Kilograms per sq. meter.

Kilograms per sq. Cm. = .968 atmosphere.

Atmosphere = 1.033 Kilograms per sq. Cm.

Hydraulic Formulas

Lb. per sq. in. = 0.434 × head of water in ft.

Head in feet = 2.3 × pounds per sq. in.

Weight per cu. ft. of water = 62.4 pounds.

Weight per gal. of water = 8.33 pounds.

Gallons per cu. ft. = 7.48

Definitions

Dyne = Unit for force

Erg = Unit of work

Watt = Unit of power = Volt ampere

Dyne is the force which acting on a mass of one gram driving on second will give it a velocity of one Cm. per second.

1 Erg = 1 Dyne—Cm. = .00000007373 ft. lb.

1 Watt = 10 million ergs per second.

1 Watt = 7373 foot-pounds per second.

1 Watt = .00134 H. P.

Miscellaneous

Kilogrammeter = 7.233 foot-pounds

Foot-pounds = .1384 kilogrammeter

Cheval (French horse power) = .986 h. p.

Horse-power = 1.014 cheval

Litre per second = 2.12 cu. ft. per minute

Litre per second = 15.85 U. S. Gallons per minute

Equivalents of Electrical Units

1 Kilowatt = 1000 watts

1 Kilowatt = 1.34 H.P.

1 Kilowatt = 44,257 foot-pounds per minute

1 Kilowatt = 56.87 B.T.U. per minute

1 horse-power = 746 Watts

1 horse-power = 33,000 ft.-lbs. per minute

1 horse-power = 42.41 B. T. U. per minute

1 B. T. U. (British Thermal Unit) = 778 foot-pounds

1 B. T. U. = 0.2930 watt-hour

1 joule = 1 watt-second

TABLE OF CHEMICAL SOLUBILITIES

THE following table will serve as a guide when preparing stock solutions of photographic chemicals. As a solution is likely to become cooled in winter to a temperature approximately 40° F., it is not advisable to prepare a stock solution stronger than is indicated by the solubility of the chemical at this temperature.

Substance	*Ounces of chemical in 100 ozs. (fluid) of saturated solution at* 40° F. (4.4° C.)	70° F. (21.1° C.)
Acid, acetic (any strength)	mixes in all proportions	
Acid, citric	78	88
Acid, oxalic	7¼	14½
Acid, tartaric (dextro)	73	78
Acrol or amidol (see diaminophenol hydrochloride)		
Alum, ammonium	6¼	15½
Alum, iron	48	59
Alum, potassium	6¼	11½
Alum, potassium chrome	15½	20½
Amidol or acrol (see diaminophenol hydrochloride)		
Ammonia solution	mixes in all proportions	
Ammonium bromide	52	57
Ammonium carbonate	26	31
Ammonium chloride	26	30
Ammonium iodide	104	109
Ammonium oxalate	2¾	5¼
Ammonium persulphate	52	62
Ammonium thiocyanate or ammonium sulphocyanide	62	73
Ammonium thiosulphate, anhydrous	83	88
Borax (sodium tetroborate)	2½	7¼
Caustic potash (see potassium hydroxide)		
Copper sulphate, crystal	26	31
Diaminophenol hydrochloride (acrol or amidol)	20½	26
Elon (monomethyl para-amino phenol sulphate)		
Ferrous sulphate	5¼	8¼
Formalin	29	41
Hydroquinone	mixes in all proportions	
Hypo (see sodium thiosulphate)	4¼	6¾
Kodelon (see para-aminophenol oxalate)		
Lead acetate	31	47
Mercuric chloride	4	6¼
Para-aminophenol oxalate (kodelon)	1¼	2½
Potassium bichromate	6¾	14½
Potassium bromide	50	56
Potassium carbonate, anhydrous	83	85
Potassium chloride	26	31
Potassium citrate	93	104
Potassium cyanide	46	52
Potassium ferricyanide	30	36
Potassium ferrocyanide	17½	26
Potassium hydroxide (caustic potash)	78	83
Potassium iodide	99	104
Potassium metabisulphate	47	57
Potassium oxalate	29	36½
Potassium permanganate	3¼	6¾
Pyrogallol (pyro)	36	57
Silver nitrate	109	135
Sodium acetate, anhydrous	31	36
Sodium acetate, crystal (trihydrate)	52	62
Sodium bicarbonate	7¼	9¼
Sodium bisulphate	52	52
Sodium bromide	67	73
Sodium carbonate, anhydrous	10¼	24
Sodium carbonate, crystal	29	65
Sodium chloride	31	31
Sodium hydroxide (caustic soda)	50	83
Sodium phosphate, dibasic crystal	6½	24
Sodium sulphate, anhydrous	5¼	20½
Sodium sulphate, crystal	10¼	41
Sodium sulphide, fused	13½	17¾
Sodium sulphide, crystal	36¼	47
Sodium sulphite, anhydrous	17½	28
Sodium tetraborate (see borax)		
Sodium thiosulphate, (hypo) crystal	73	93
Uranyl (uranium) nitrate	114	130

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says . . .

"I'se des thinkin' when I grow up I'll be a famous cinen..a..a...cin..e..ma.. well, a cameraman like my Dad, 'n go places 'n make bootiful pictures like he does."

"My muvver says if I do my folks will never get a chance to know me . . "

"So . . . ho, hum! . . . des I'll go to sleep."

LONE STAR RANGER

HARMONY AT HOME

ROUGH ROMANCE

QUALITY

ACCURACY

SPEED

DANIEL B. CLARK
A.S.C.

VICTOR MILNER

A. S. C.

PARAMOUNT STUDIOS

Henry Sharp

A. S. C.

Metro-Goldwyn-Mayer Studios


C. CURTIS FETTERS
A.S.C.

GLENN R. KERSHNER

A. S. C.

The Man Who Draws the Cartoons in the American Cinematographer

That is his hobby. His profession is that of a

CINEMATOGRAPHER

During the past year associated with Sol Polito, Lee Garmes, Sid Hickock, Arthur Edeson, Clyde DeVinna, Hal Mohr, Karl Struss on "Coquette," Ernest Haller on "Son of the Gods," latest on "Adios," a First National Picture.

Don't miss the cartoons for the coming year in the AMERICAN CINEMATOGRAPHER

Ian Keith

WITH BEST WISHES TO MY FRIENDS . . .
THE CAMERAMEN

Charles G. Clarke, A. S. C.

Cinematographer

"SO THIS IS LONDON," STARRING WILL ROGERS

"THE SONG OF KENTUCKY"

"THE RED DANCE," STARRING DOLORES DEL RIO

"FOUR SONS"

(In Association with George Schneiderman, A. S. C.)

Jackson J. Rose

A. S. C.

"Show Boat"

"Mother Knows Best"

"Captain of the Guard"

GILBERT WARRENTON, A. S. C.

Director of Photography

Al Gilks

A. S. C.

Charles Rosher

A. S. C.

Ray June

A. S. C.

Cinematographer

"ALIBI"

"LOCKED DOOR"

"NEW YORK NIGHTS"

"PUTTIN' ON THE RITZ"

"BRIDE 66"

UNITED ARTISTS

BEST WISHES *to* MY FRIENDS
of the A. S. C.

GEORGE O'BRIEN

ERNST LUBITSCH

With the best wishes
for the success of the A.S.C.
and the Cinematographic Annual
from a man who appreciates
the True worth of the
Cinematographers.