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CONTENTS

The IR System: An Optical Method for Increasing Depth of Field — ALFRED N. GOLDSMITH — 3

A New Dichroic Reflector and Its Application to Photocell Monitoring Systems — G. L. DIMMICK — 36

Production and Release Applications of Fine-Grain Films for Variable-Density Sound-Recording — C. R. DAILY AND I. M. CHAMBERS — 45

Laboratory Modification and Procedure in Connection with Fine-Grain Release Printing — J. R. WILKINSON AND F. L. EICH — 56

A Note on the Processing of Eastman 1302 Fine Grain Release Positive in Hollywood — V. C. SHANER — 66

Report of the Theater Engineering Committee — 74

Report of the Standards Committee — 87

Some Equipment Problems of the Direct 16-Mm Producer — L. THOMPSON — 89

Current Literature — 103

Society Announcements — 104

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THE IR SYSTEM: AN OPTICAL METHOD FOR INCREASING DEPTH OF FIELD*

ALFRED N. GOLDSMITH**

Summary.—*The depth of field of a corrected lens system is determined by its focal length, its relative aperture, and the permissible diameter of the "in-focus" image of a point source.*

The limited depth of field in motion picture photography restricts freedom of action in large parts of the set, dictates a stylized, protracted, and costly studio procedure, and affects the dramatic value and audience appeal of monochrome or color pictures.

Previous attempts to increase lens depth of field have been scientifically unsound and unsuccessful in practice. The new IR System, described in this paper, is based on a division of the set into optically appropriate regions, each region having identifiable illumination, with the identification and differential focusing at the camera of all regional images within a single exposure. Thus greatly increased depth of field in straight and process shots becomes available.

By a further modification in regional lighting, a number of such increased-depth takes can be simultaneously made from different distances or at various angles, each such take having its own different and appropriate lighting.

1. INTRODUCTION

The following paper is submitted as a report of progress made by the staff of IR System.† In it there will be described the solution of a long-standing problem in the field of optics, namely: the attainment of greater depth of field than is obtainable by any previous method of utilizing a lens system for image formation. The solution is particularly applicable in the fields of photography and television under conditions of controllable lighting of the external objects to be depicted. In this paper there will also be included methods for demonstrating the correctness and effectiveness in practice of the increased-range system which, as stated, has been invented to meet the need for increased depth of field, as well as indications of certain of

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† As described in part in United States patents numbers 2,244,687 and 2,244,688.

the directions in which the practical evolution of the IR System may reasonably be expected to proceed under studio conditions.

2. NEED FOR INCREASED DEPTH OF FIELD

It is correctly axiomatic among optical experts that the depth of field of a lens is a function only of the focal length of the lens and its working or relative aperture (together with the permissible diameter of the "circle of confusion" forming the image of a point source). Thus, for a lens of any specific focal length and aperture (or "speed"), focused for a definite object distance, and for a given permissible size of the circle of confusion of the point image, the depth of field is readily calculable and is unchangeable by any known method. Thus every objective lens in effect divides the object space into two portions. One of these portions is a relatively thin slab, based on the focused plane, and extending optic-axially forward and backward to an extent determined by the depth of field. Within this slab or region, all objects are said to be depicted "in focus" on the conjugate plane of the photographic film or other photo-sensitive surface. The other portion comprises the entire remainder of the object space, and all objects within that second portion are depicted "out of focus." For object distances notably less than the hyperfocal distance of the lens, the second portion of space, wherein objects are incorrectly depicted as out of focus, is vastly greater in extent than the first portion of space within which they are depicted in focus. This is a serious and inevitable limitation of all lens systems, and naturally has a profound influence on optical imagery in the motion picture field. Further, it influences and indeed controls the method of studio photography, script writing, separation of and relationship between various takes, editing, cutting, and the final effect of the produced picture. It has required the cameraman as well as the writer, director, actor, and editor to accommodate themselves to the rigid framework of a cramping optical law. Sincere tribute must be paid to the effort and ingenuity of these workers in their attempt to circumvent or at least to minimize the difficulties of photography within these restrictions. But, at best, an artificially limited presentation has resulted, including a number of conventions which have been accepted by the producers and the audience alike in the absence of anything better. Sometimes, indeed, cameramen have resorted more or less in desperation to radical measures such as using extremely short-focus

lenses stopped far down in order to secure somewhat increased depth of field. In so doing, they have inevitably introduced the exaggerated perspective and pictorial unnaturalness resulting from the use of such lenses, and have either over-illuminated the stage with resulting eyestrain and discomfort to the actors or have produced a contrasty, underexposed, "chalk and coal" picture or both.

On the other hand, the human eye has in effect a practically unlimited depth of field. The re-focusing of the eye for any desired object distance is so nearly instantaneous that the viewer is unaware that any part of the field of view is ever out of focus. Thus, in natural and real life, persons with normal sight are totally unaware of any limitation in the visual depth of field. Again, anyone who, in viewing a legitimate stage performance, found that he could see the people in the foreground sharply defined but that the people in the background were blurred or fuzzy, would at once and properly consult his oculist.

The camera lens, by way of contrast, has a very limited depth of field. Considering the most generally used lens of 50-mm focal length operating at a speed of, say, $f/2.8$, it is interesting to note that the back depth of field for an object distance of 5 feet is only 6 inches; for an object distance of 8 feet is 1 foot 2 inches; and for an object distance of even 12 feet is only 3 feet 2 inches. It is within such circumscribed regions that conventional photography must be carried out. The follow-focus adjustment is of course no solution of the problem since it applies only to one given object distance at any instant and does not in the least solve the major pictorial and dramatic problem of successfully depicting significant action occurring *simultaneously* at widely different distances from the camera.

Thus, in each take, the motion of the actor is definitely and necessarily limited by chalk lines on the floor. This regulates the nature of the action which can be included in the script; prevents the usual and natural action of various groups simultaneously at different distances from the camera; forces the choppy method of frequent jumping back and forth between long shots, medium shots, and close-ups with all the resulting multiplicity of takes, and difficulties in maintaining mood and matched action (not to mention matched sound); and cannot but affect adversely the naturalness of acting for the motion picture as compared with that of the legitimate stage. It is appropriate briefly to quote certain major Hollywood figures in this regard:

"Hal Mohr, when assigned to *Green Pastures*, decided the dramatic power of the photograpy would be considerably increased if, instead of breaking up the action between a figure in the foreground and another in the background into a series of individual close-ups, the action could be shot at the same time with one lens."

This viewpoint favoring continuity of photography through the entire depth of the set is significant. The reaction of the actor to the restrictive effects of limited depth of field is indicated in the following quotation:

"Hollywood, in the opinion of Eduardo Ciannelli, would be a paradise for the stage actor if it weren't for the chalk lines. . . . And he pointed to his feet, to the veritable chalk lines the screen player must toe. 'If it weren't for those,' Ciannelli went on, 'which are there to keep you from walking out of the camera range or getting so close you're out of focus or so far away they can't see you, films would be for the stage player all he has ever dreamed of.' "

The following comment by Allyn Joslyn expresses a similar thought in another form:

". . . Finally it is my turn to get in front of the cameras. I can't turn my head too far to the left or I'll be out of line. I can't take a step too far to the right or I'll be out of focus. In other words, there I am, penned in a tiny space, realizing that unless I stay in it and give all I've got they will have to make a retake."

The effect of this claustrophobic optical atmosphere on the actor is further graphically indicated by Paul Muni in the following:

"To act in motion pictures is to act in a world in which mechanical problems beset the actor on all sides; his performance is governed by them, he can not escape them. From the time he appears on the set, his steps are caged by chalk marks, and focal distances . . . and his image can only be seen if he moves with care within the cage."

Speaking of the difficulty experienced in economical set construction when panning shots are made under present conditions, Hans Dreier says:

"A more involved example would be one in which the camera precedes an actor walking along, then swings away from him to point out a person in another part of the room. Such a set-up sometimes means the construction of large sets which are subsequently overlooked, because the camera is so close to the actor that everything else is out of focus."

It is necessary to stress here the preceding points since many studio workers have become so accustomed to present-day practice that its limitations have come to be regarded as inevitable, natural, and in-

herently to be accepted. Indeed, present motion picture technic is fundamentally based on these optical limitations of the objective lens. Studio practice simply does its best within the limits of present-day optics. Some cameramen and a part of the audiences have become so accustomed to the present restrictions that they hardly realize the wealth of improvement which would be available were these restrictions to be removed. It does not occur to most people that the present abrupt succession of long, medium, and close-up shots necessarily results in large measure from the limitations of the lens. Present practice requires continually shifting the point of view, wearisomely accumulating many takes of each scene or action, painstakingly matching up successive takes, "covering up" in cutting and editing, delay and increased cost in production, unnaturalness in the acting and in the corresponding effect on the audiences, and a less economic and dramatic set-up than would otherwise be attainable.

The availability of increased depth of field would gradually bring about a marked revolutionary change in methods of production, greater flexibility, considerable economies, and simplifications in camera technic. To the audience, the pictures would more closely resemble legitimate-stage performances or even real life. It may be added that conventional pictures of today, with their limited depth of field, cause an unconscious irritation or strain to the audience. While the foreground may be in focus, the background is usually blurred. In accordance with long custom and experience, the eye of the viewer attempts to bring the background into sharp focus and of course fails. This continual attempt and failure is a physiological strain and a psychological disappointment.

In the case of color motion pictures, increased depth of field is, if possible, even more essential. Color pictures, when out of focus, are not merely blurred but also "out of color." Thus, a red-and-white checked dress when out of focus is merely pink—which is something quite different from the original. An out-of-focus background of colored objects usually shows curious bronzy greens, nondescript browns, and other unprepossessing and incomprehensible color effects.

From the viewpoint of the film manufacturer, the limited depth of field now current somewhat nullifies the advantages sought in the painstaking production of fine-grain film. The high possible "load factor" of the film is not realizable under present conditions. Sharpness of delineation is limited to a relatively small portion of the depicted space, and thus most of the film might as well be extremely

coarse-grained so far as any picture-carrying capabilities are concerned.

In Fig. 1 is shown schematically the diameter of the circle of confusion of the image of a point source at various distances from the lens (*dotted curve*), together with the equivalent resolution, expressed in terms of "lines" comprised in the height of the picture (these being adjacent lines like those used for scanning in television practice) (*solid curve*). There is also shown the "useful" definition realized in the picture, together with the "lost" definition. It is clear enough

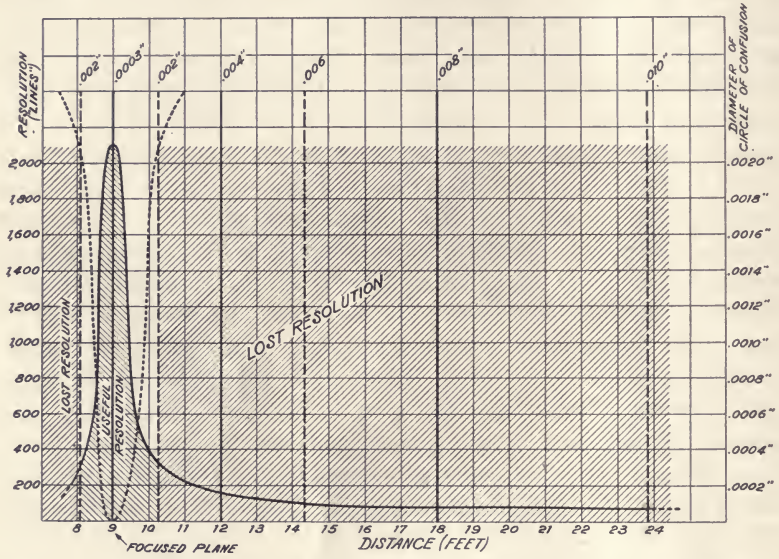

FIG. 1. Picture resolution *versus* distance, as controlled by depth of field. Focal length, 50-mm; aperture, *f*/2.3.

that present practice constitutes an uneconomic combination of fine-grain film and coarse-grain images.

It is assumed that a resolution of 70 lines and equally wide spaces between them per millimeter can be achieved in the focal plane, this corresponding to 2100 lines resolution according to the present television practice. It is not meant to imply that such resolutions are commercially attainable at all times in the negative nor that they can be maintained in projection on the theater screen. However, they represent a possible delineatory capability of the film. The size of the image of a point source on the film is indicated for various distances

from the lens on the vertical lines marking those distances. The corresponding approximate resolution is indicated on the curve. It is obvious that, except for one sharp maximum, the resolution of the picture soon falls to inacceptable values—and indeed to values rejected in the past as inadequate for television service in the home. Outside of the region embraced by the narrow maximum of resolution in question, the capabilities of the film, the script, and the actors are unrealizable on the theater screen.

Another fundamental need for increased depth of field will be in the domain of three-dimensional pictures. No matter what type of stereoscopy is used in the future for that purpose, it is obvious that for naturalness of the three-dimensional pictures the depth of field must appreciably cover the depth of the object space to be depicted. There is no naturalness to "three-dimensional fog banks," so to speak —and that is all that can be produced in the out-of-focus background of a stereoscopic picture.

Once increased depth of field becomes available, there will naturally be a demand for a method of making simultaneous multiple angle shots. That is, it will be preferred to shoot the same action simultaneously from various viewpoints and distances, with all parts of the picture in focus, and with each camera viewing the action illuminated by a particular type of lighting appropriate to the effect which is desired. Further operating economy and naturalness in the acting and resulting picture would thus be attained. The editor and cutter are given a far wider opportunity to do a masterly job with the availability of multiple-angle-shot negatives of the same action, taken simultaneously, and in focus throughout.

It was with such major considerations in mind, that the attempt was made by the staff of IR System to solve the corresponding problems. At first sight, the task seemed sufficiently discouraging.

3. HISTORY OF PREVIOUS ATTEMPTS TO INCREASE DEPTH OF FIELD

Numerous unsuccessful attempts in the past have sufficiently demonstrated the difficulty of the problem, as well as its importance. Previously suggested methods have all contained more or less subtle and concealed fallacies. As a natural consequence, attempts to solve the problem of depth of field had acquired something of the low repute of "perpetual motion" inventions in the minds of most reputable scientists. The point had been reached where anyone proposing an increased depth-of-field method had been more or less automatically

classified as flying in the face of scientific facts, laws, and limitations. And it must be admitted that the previous attempts in this direction had largely justified this classification.

Broadly, all previous methods were based on a degradation of image quality. That is, if the permissible diameter of the (circle of confusion of the) image of a point source in its conjugate focal plane is increased, depth of field is also increased. But the problem has not in the least been solved. It has not even been evaded. Poor photographic quality and unsharp images are obviously too high a price to pay for depth of field. The problem instead is just this: to increase depth of field *while maintaining image sharpness and photographic quality*. Contrariwise, the previous attempts can be readily classified on the basis of the method selected for degrading the image quality. None of them solved the depth-of-field problem with maintained pictorial quality.

The two chief sub-groups of these image-quality-degradation methods are the following. Both are theoretically incorrect and physically unworkable and inoperative. They are here mentioned for the sake of completeness.

Group 1. Aberrational Pictures.—In this method, optical aberrations of some sort are deliberately or unconsciously introduced into the objective lens system. Usually spherical aberration or zonal aberration or both have been introduced, although comatic (and even chromatic) aberrations have also been included. Sometimes the aberrations have been introduced in the design or construction of the lens, and sometimes they have been added by placing an additional aberration-producing component lens in front of the main objective.

The resulting images were not sharp or clear anywhere. They were no solution of the depth-of-field problem. Increased depth of field in the true sense does not result from looking at pictures through a fog, a haze, or a diffusing gauze.

Group 2. Average-Focus Pictures.—In this method, the entire set from foreground to background is illuminated steadily. The lens is moved axially (actually or in effect) during the exposure of each frame so that it is focused on the foreground during part of the exposure and on the background during another part of the exposure. The fallacious and unplausible claim is made that, during the portion of the exposure that the foreground is in focus, it is sharply photographed; and similarly during the portion of the exposure when the

background is in focus, it is photographed in focus; and, therefore, add the advocates of this method, the resulting picture is completely in focus!

The facts are quite otherwise. While the lens is focused on the foreground, the out-of-focus background is also photographed since there is nothing discriminatory about the lens or the film. Likewise, when the lens is focused on the background, the out-of-focus foreground is photographed. As a result, the images of objects at any and every distance from the lens consist of an in-focus component overlaid and badly blurred by an infinity of out-of-focus pictures of the objects at that distance from the lens. Obviously, the combination of an in-focus picture with an infinity of out-of-focus pictures is a blurred picture in every plane, and not a sharp picture as claimed.

The fallacy in this method is as evident as the following. A teaspoonful of pure water is mixed with many teaspoonfuls of water each containing increased proportions of a deadly poison. Will the mixture be pure water, or will it be poisonous? Substitute for "pure water" a sharply focused component picture, and substitute for "poison" an out-of-focus component. It then becomes clear enough that the average-focus method is merely another way of trading image quality for depth of field, and is therefore totally inacceptable.

As indicated above, attempts have also been made to increase depth of field by using very short-focus lenses greatly stopped down. This method is theoretically correct within its limits, but it is useless for acceptable photography. The requirements for correct perspective in the projected picture are well known and not to be slighted. The short-focus lens in the camera gives pictures which, when projected in the theater and observed at normal viewing distances, are badly distorted and show exaggerated perspective. Thus the requirements for correct perspective are shockingly violated in this type of picture. Further, motion of the actors is intolerably peculiar with strange variations in velocity which are utterly unlike those in real life. Then, too, the stopped-down lens leads to vastly increased and obviously inacceptable studio lighting for a nearly correctly exposed picture or, alternatively, to considerably increased and just tolerable studio lighting with an underexposed and contrasty negative.

In the problem of depth of field, as in some other human problems, "we thus learn from history that we learn nothing from history"—except perhaps what to avoid.

4. SPECIFICATIONS FOR AN INCREASED-RANGE SYSTEM

In view of the confusion which has existed in some quarters as to what constitutes a system for true increase in depth of field, it is deemed appropriate to list below the specifications and general characteristics of such a system. The following description then covers an acceptable method for adding to depth of field without optical or esthetic deterioration of the picture rather than a system which merely sacrifices important optical or pictorial qualities to secure an apparent increase in depth of field. The following are, however, admittedly strict specifications.

(*a*) The system shall be usable for either *black-and-white or color* pictures.

(*b*) It shall be usable for *still-picture or motion-picture* photography.

(*c*) It shall be usable for *photography or for television* and the like.

(*d*) The system shall enable using *standard lenses* of the highest degree of correction of optical aberrations then current in the art.

(*e*) It shall enable using lenses of any *normal and usual focal lengths.*

(*f*) It shall enable the use of normal lenses at the *usual large apertures.*

(*g*) And above all, there shall be *no deterioration of picture quality* or sharpness as the result of the use of the system.

(*h*) The *sharpness* of focus of objects *in any portion of the object space* shall be reasonably *controllable.* This condition, which is preferred but not mandatory, is met by the IR System.

(*i*) *No* extensive or unduly *cumbersome changes in camera* construction shall be necessary.

(*j*) The *handling of the camera* and its finder shall be essentially *conventional;* and increased-range pictures shall be available in the finder to guide the cameraman as well.

(*k*) It shall require *no more total light* on the actors than for ordinary photography.

(*l*) It shall enable the use of lighting to obtain any of the effects obtained by *conventional lighting* and photography.

(*m*) Setting up the *lighting* of the set shall require little specialized optical knowledge, and shall be conveniently possible *by the usual experienced electricians.*

(*n*) It shall be flexibly *adaptable to* composite or *process shots* as well as to miniature work.

(*o*) It shall preferably enable making a number of *simultaneous angle shots* from different viewpoints, with different types of lighting; and each of these shall have increased depth of field as required.

While the above are extremely difficult specifications, they have been met by the newly developed IR System. So far as is known, they have never previously been met; and there is reason to believe that no other method of meeting these specifications with conventional optical elements alone is possible.

5. GENERAL PRINCIPLES OF THE IR SYSTEM

In ordinary photography, each frame or picture represents a view from a uniquely focused lens of an entire and overall-illuminated object space. In the IR System, each frame or picture represents the composite of a number of views made by a multiply focused lens, each of which views covers only a region or division of the object space so selected that the picture of such region is altogether in focus. Thus the IR System includes the photography within a single exposure period (single frame) of the various adjoining regions of the object-space in such fashion that

(*a*) each region has an identifiable illumination, with minimized spillover of illumination of other types, and

(*b*) the identifiable illumination from each region is first identified and in effect segregated, and, second, brought to the same focal plane as that from all other regions by means of a differential-focusing device.

The identifiable regional illumination may be of the following types:

(*a*) It may be suitably polarized light. This method is not recommended in general because of the non-retention of the plane of polarization of light on reflection from most surfaces.

(*b*) It may be appropriately colored light. In this case, each region in the object space is illuminated by light occupying a different spectral range, thus enabling its later identification either by color filters or by the differential refraction (dispersion) of some refracting system. The method amounts to establishing a selected color configuration (*e. g.*, a spectrum, broadly speaking) axially through the object space, and then introducing a compensating amount of longitudinal chromatic aberration into the objective lens system so that the colored light from each region is brought to the same focal plane and there correctly imaged.

(*c*) It may be correctly timed illumination. In this instance, the total time for each frame exposure is divided into a number of portions. Each region in the object space, as defined below, is illuminated during a selected portion or portions of the total available exposure time *and is not illuminated at any other times during the exposure period*. This last proviso is fundamentally novel, and is important in the realization of the method. At the camera lens, a differential-focusing device is synchronized with the light coming from each corresponding region in such fashion that the light from each region is brought to the same focal plane. The resulting picture therefore has

increased depth of field since it consists in effect of the composite of a number of pictures each of which is inherently in focus, which pictures in their totality form a complete picture of the object space.

This method amounts, in its simplest form, to sending a wave of illumination (in the form of an axially extensive and steadily deepening slab of illumination) in some systematic fashion through the object space, and pacing it by a synchronized wave, so to speak, of correlated focusing of the objective lens such that the light from all objects on the set is brought to the same focal plane. It also amounts to a sort of third-dimensional luminous scanning of the set followed synchronously by the appropriately coördinated focusing of the lens so that the picture of the entire set is in focus on the film.

Methods *a*, *b*, and *c* above can be combined in various ways. It is not necessary here to go into details in that regard.

Method *b* as described above can be used only for black-and-white or other monochrome photography. It is interesting in that there are no moving parts involved. Method *c* will generally involve at least some moving parts. It can be used for either black-and-white or color photography.

Method *c*, as suggested above, is complementary or supplementary to the usual two-dimensional television scanning. It is in fact a form of planar scanning in the third dimension (that is, parallel to the optical axis of the objective lens).

Inasmuch as the focusing of the images of objects lying within any region in the set is dependent on the identifiable illumination of that region, it is clear that the image of each region can be controllably focused or softened to any desired extent regardless of the sharpness of focus of other regions. Thus individual objects can be changed in sharpness by altering or destroying the identifiable characteristic of the light falling on such objects. Accordingly, it is possible to produce what would otherwise seem to be an optical anomaly, namely, and as an example, pictures in which the foreground and background are sharply focused but in which the middleground is softened to any desired extent. The imaginative director and cameraman will readily see numerous dramatic and comic possibilities in so versatile a type of photography.

6. DEFINITIONS OF IR SYSTEM TERMS

Multi-regional photography by the IR System is so novel a method of optical imagery that it naturally leads to some new optical con-

cepts which, for convenience, should be given appropriate names and defined. This has been attempted in the following set of definitions of terms which have been found conveniently usable by the workers in that field. The list is incomplete since a considerable number of the concepts and methods involved in the IR System are beyond the scope of this paper, and accordingly the terms involved in those relations are not here included.

Region.—A portion of space symmetrical about the optical axis of an objective lens, based upon a central plane of sharp focus, and bounded externally front and rear by surfaces corresponding to a predetermined and maximum tolerable value of the diameter of the circle of confusion of the image of a point source placed upon such surfaces.

Division.—A portion of space symmetrical about the optical axis of an objective lens, based upon a central plane of sharp focus, and bounded externally front and rear by surfaces corresponding to a predetermined value of the diameter of the circle of confusion of the image of a point source on such surfaces, such value being less than the tolerable maximum. A division thus resembles a region but corresponds to less than the full depth of focus of the lens. Thus, there will be more divisions in a given object space than there are regions.

Differential Focuser (*briefly, Diffo*).—An optical element placed suitably in relation to an objective lens and capable of rapidly shifting the back focal plane thereof according to a predetermined time schedule during a picture-making period, but without the introduction of perceptible aberrational errors in the conjoint optical system.

Space Spillover.—The amount of light intended for illumination of one region (see above) which actually reaches another region (expressed in percentage of the light normally sent into the second region). The definition can also be applied to divisional space spillover.

Time Spillover.—The amount of light intended for illumination of a given region within a given period which begins before or lasts beyond such period of illumination (expressed in percentage of the normal illumination of that region during that period). This definition may also be applied to divisional time spillover.

Space Registration.—The deviation from exact registration during a complete exposure between the outer edges of opaque objects in a frontal region and the inner edges of the thereby-occulted or masked outlines in a region further removed from the lens.

Motional Registration.—The deviation from exact registration dur-

ing a complete exposure between the positions or outer edges of moving objects in a frontal region and the inner edges of the thereby-occulted outlines in a region further removed from the lens.

For convenience of reference, it may be here added that space registration effects result from the relatively unfocused edges of frontal-region objects, acting as masks during the photography of further removed regions. Motional registration effects, on the other hand, result from the shifted edges of frontal-region objects in motion at the time of photographing further removed regions.

7. OPERATION OF IR SYSTEM IN STUDIO

In order to make the method of operation of the timed-illumination form of the IR System clear, a schematic arrangement is shown in

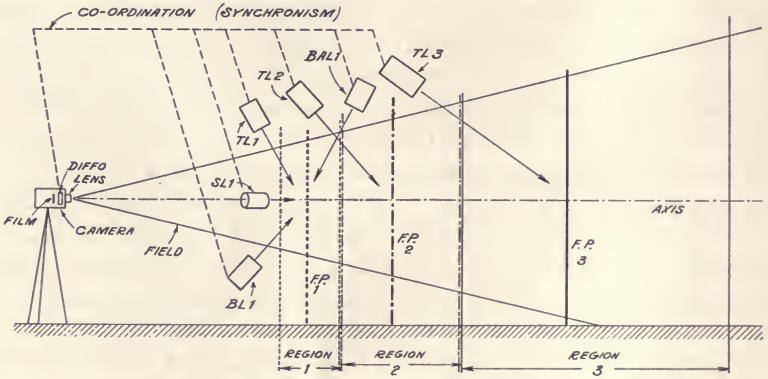

FIG. 2. Regional illumination and camera arrangements of a set according to the IR System.

Fig. 2 illustrating the illumination of the set. The central planes of the regions are indicated, but it should be remembered that these planes are somewhat forward of the geometrical center of the region since the back depth of field always exceeds the front depth of field. The front and back boundaries of the regions are also shown. The regional illumination in each case is seen to be directed into that region only, and with minimum space and time spillover. The camera shutter is replaced by a differential focuser or diffo, which operates synchronously with the flashing of the lights in each region. This changes the position of the focal plane systematically so that each region is imaged in the same plane, namely, that of the film.

Considering Region 1, *F.P. 1* is the central or focal plane. Top lighting into the region is indicated by *TL 1;* side lighting by the oblique lamp *SL 1;* bottom lighting is indicated by the lamp *BL 1;* and back lighting for Region 1 by the lamp *BAL 1.* Similarly top lighting for Region 2 is indicated by *TL 2,* and for Region 3, by *TL* 3. The coördination or synchronizing of the illumination from these various lamps with the angular position of the diffo in the camera is schematically indicated by the dashed lines in Fig. 2.

It is obvious that there are many ways of focusing differentially and of timing the regional illuminations in synchronism with the phase or position of the diffo. Typical examples of these will be described further below.

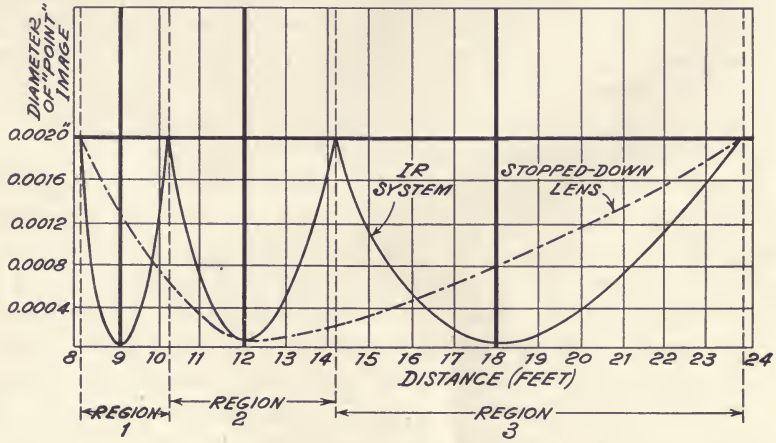

FIG. 3. Diameter of point-source image *versus* distance for IR System operation. For lens of focal length of 50-mm and stop *f*/2.3.

The system shown in Fig. 2 leads to an interesting form of the curve connecting distance from the lens and diameter of the circle of confusion in the image of a point source at the corresponding distance. This multi-cusped curve is shown in Fig. 3. The positions of the central planes of the regions, the regional boundaries, and the maximum permissible circle-of-confusion diameter (taken as 0.002 inch for 35-mm film) are all indicated on the drawing. The left-hand loop corresponds to ordinary photography, while the complete curve corresponds to the increased depth of IR System photography.

By way of comparison, there is also shown on Fig. 3, as a dot-dashed curve, the depth of field of a lens of the same focal length

stopped down to the point where it covers the same total or overall depth of field as three-regional IR System photography. It will be seen that the results of the two methods are even then by no means identical, or indeed equivalent in photographic effect, that is, even when the stopped-down lens is used to obtain equal overall depth. The IR System curve shows clearly three minima, corresponding to planes of sharpest or "absolute" focus. Thus, it is quite possible to place the central or most sharply focused plane of the rearmost Region 3 in the IR System at the back wall of the set or, alternatively, on the screen forming the back drop for rear projection composite shots (as described more fully below). In this way, the important background is shown in completely sharp focus, as are also objects at several other distances from the lens—and, of course, all other objects in the field are depicted "in focus"—that is, within the acceptable limits of sharpness. In the case of the stopped-down lens, on the other hand, only objects at a *single* distance from the lens can be in absolute focus; and the important background, for example, is less sharp than this, although perhaps acceptable.

Using IR System photography, it is also feasible to divide the object space into more divisions than the number of optical regions it comprises. In that case, the curve corresponding to Fig. 3 will have as many minima corresponding to absolute focus as there are divisions, and thus there will be more minima than there are regions. Furthermore, in this arrangement, the maximum value of the diameter of the point-source image will always be less than the permissible maximum of 0.002 inch for 35-mm film, and this diameter and the corresponding sharpness are in fact under control with the arrangement in question.

Up to this point it has been tacitly inferred that the boundary surfaces of the various regions in IR System photography are plane surfaces perpendicular to the optical axis of the lens, as schematically indicated in Fig. 2. Such, however, is not the case. It is well known that the speed of a lens is always less for the edge of the field than for the center because, in the main, of the occulting effect of the lens tube and the interior stops for oblique passage of image-forming rays through the system. Thus the depth of field at the edges is greater than at the center. In consequence, the boundary surfaces of the regions are as indicated in Fig. 4. The central or focal plane of Region 1 is indicated by *F.P. 1*, and the dotted lines *F1* and *B1* are sections of the surfaces of revolution comprising, respectively, the front

and rear boundaries of Region 1. Similarly *F.P. 2* is the central plane or Region 2, and the dot-dashed lines *F2* and *B2* represent the front and rear boundaries of Region 2; while *F3* is the front boundary of Region 3, of which *F.P. 3* is the central or focal plane.

It is characteristic of the IR System that the illumination of any one region shall be restricted with minimum spillover to that region. From Fig. 4, it is obvious that oblique regional lighting in Region 1 can enter the region at considerable angles with the optic axis of the camera lens without violating the condition in question. Increasing obliquities are available for the illumination in the successively further removed regions, as indicated by *O.R.L. 2* and *O.R.L. 3*, respectively. A similar comment as to permissible obliquity of back lighting applies, as indicated by the back oblique regional light *B.O.R.L. 1*

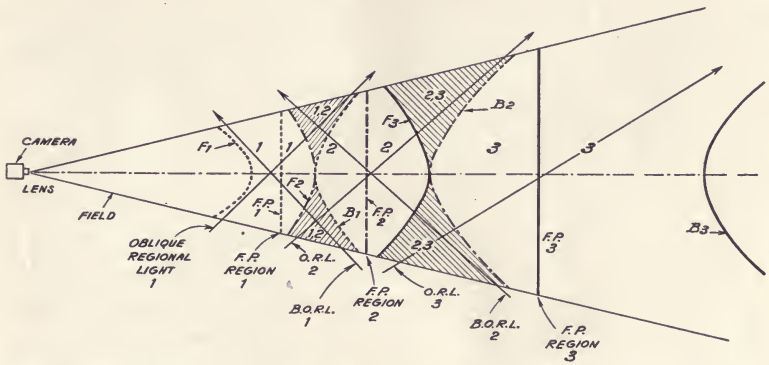

FIG. 4. Boundaries and overlap of regions according to IR System, considering center and edge speeds of lens.

for Region 1 and by *B.O.R.L. 2* for Region 2, respectively. As a result of these flexible conditions, it proves to be conveniently possible to duplicate effectively any desirable light vector (that is, magnitude and direction of luminous flux) in each region. It is also interesting to note that the cross-hatched volumes of which the cross section are indicated as *1,2* and *2,3*, respectively, in Fig. 4 can be appropriately illuminated according to the IR System requirements by light from either Region 1 or Region 2 for the volume *1,2* and by light from either Region 2 or Region 3 for the volume *2,3*. This adds to the convenience of regional lighting.

During the development of the IR System, comprehensive tables were prepared giving the regional central distances and forward and

back limiting distances for an adequate variety of focal lengths of lenses used in motion picture work and also in television, for a considerable number of lens speeds, and for numerous working conditions covering an extremely wide variety of requisite depths of field. In their totality, these tables substantially eliminate any need for computation, reference to other depth-of-field tables, or delay in the application of the IR System to any desired circumstances and needs. Using these tables and certain supplementary data, it has been regarded as interesting to determine the available "universal-focus"

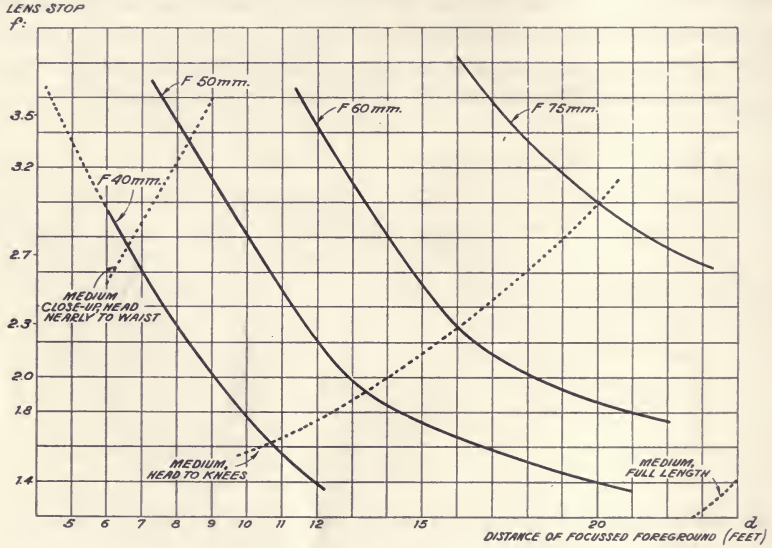

FIG. 5. Universal-focus distances *versus* apertures for current IR System practice.

capabilities of the IR System as applied in one very simple embodiment presently available. These data are shown in Fig. 5, but it should be kept in mind that by applying certain refinements and elaborations of the IR System, the performance shown in Fig. 5 can be considerably exceeded. The full-line curves in Fig. 5 show the foreground distance for each focal length and indicated stop for which the IR System will give back depth to infinity—that is, universal focus. A comparison of these curves with the hyperfocal distances of the same lens at the same stop will show the magnitude of the increase in depth of field. Thus, for a 50-mm lens at $f/2.7$, the available universal depth is from a little over 10 feet to infinity for the IR

System, whereas the hyperfocal distance of the same lens at this stop is over 60 feet!

For convenience, there have also been shown on Fig. 5 the dotted curves which intersect the full-lined curves at points corresponding approximately to photography of a "medium close-up, head nearly to waist" and "medium, head to knees," respectively. This is highly instructive to the practical director of photography and cameraman in connection with the dramatic capabilities of a photographic system which gives universal focus with reasonable lens stops from medium close-ups to medium shots, as the case may be. It may be

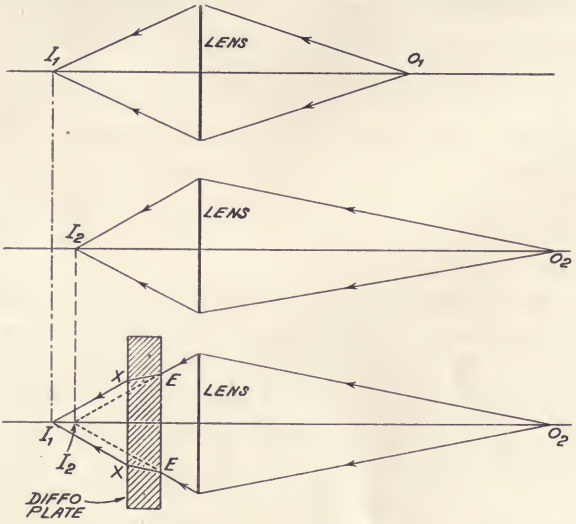

FIG. 6. Optical basis of one form of diffo used in IR System.

added that under conditions where a one-shot in a close-up can be made only with some difficulty by ordinary photography, the IR System will permit making two-shots or even three-shots with the several actors back of each other at acceptable and convenient separations.

As was mentioned above, there are a number of available methods for the differential focusing of the lens in synchronism with the sequential lighting of the corresponding regions in the object space. The basis of one form of differential focuser (diffo) is shown schematically in Fig. 6. The lens is indicated in each case by the vertical line through its center. Assume that O_1 is an object in Region 1 and that

the corresponding image is located at I_1. An object O_2 in Region 2 produces an image at I_2 closer to the lens. A diffo plate may be interposed in the path of the image-forming rays on their way to I_2. It is well known that the emergent rays in this case will be parallel to the incident rays but that the new image location I_1 will be displaced away from the lens by an amount depending upon the thickness of the plane-parallel diffo plate and its refractive index. By an appropriate selection of these constants, the image of O_2 can be brought to the same location I_1 as was the case for the object O_1. If the thickness of the diffo plate is less than a certain fraction of the focal length of the lens, no discernible optical errors will be introduced into the thereby displaced image as a result of the interposition of the diffo plate in the path of the image-forming rays.

A diffo is shown in Fig. 7 together with a corresponding aperture plate, both intended to replace the shutter in a certain standard form of studio camera, and without any modification of the camera mechanism or construction. The five diffo plates are visible in the right-hand portion of the figure, the thickest of these corresponding to the farthest region or background.

The procedure in using the IR System under studio conditions may be briefly summarized in the following. This procedure markedly resembles that for ordinary photography. It is first determined what depth of field is desired, and also the distance of the foreground plane (that is, the nearest distance to the camera at which a person in absolute focus is to be located). The pre-computed tables of the IR System will then indicate for each focal length of lens and for each desired stop, the number of regions that will be required to cover the desired depth of field. Further, these tables will give the axial distance from the lens of the front and rear boundaries of the regions in question. The edge boundaries can generally be approximately determined from these tables by a simple procedure which need not be here described. As an alternative method, of a more conservative sort, it is merely necessary to determine the depth of field of a lens of the focal length which is desired when stopped down to an extent equal to the normal lens aperture multiplied by the number of regions. Thus, if a 50-mm lens operating at $f/2.8$ is used for four-regional IR System photography, as a first and conservative approximation the working depth will correspond to that of a 50-mm lens operating at $f/11.2$ (and thus requiring sixteen times the previous amount of light on the the set!).

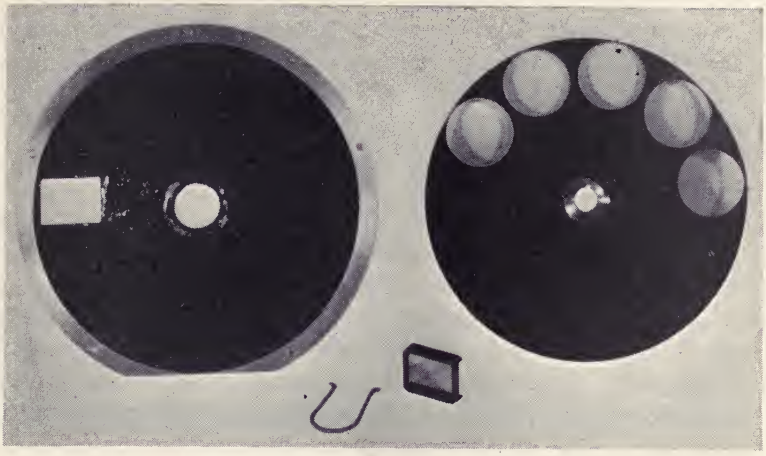

FIG. 7. Diffo and aperture plate for IR System camera operation

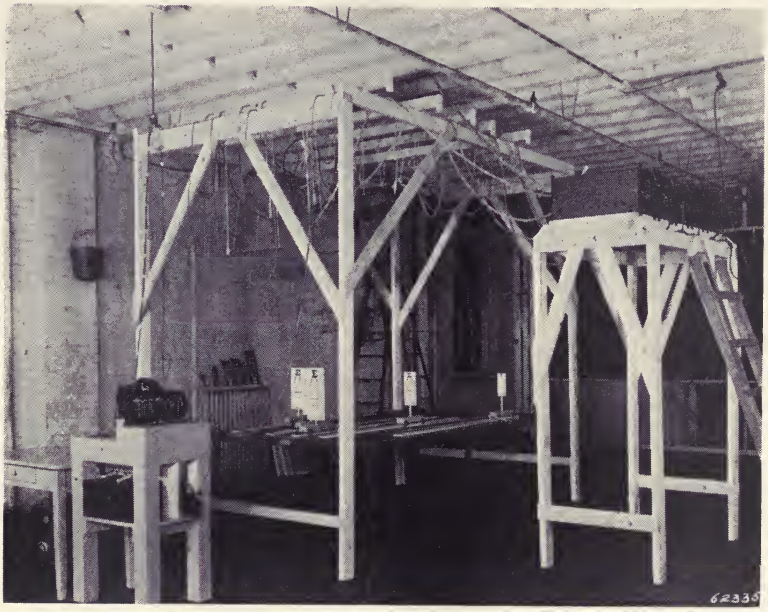

FIG. 8. Flashing gas-lamp illumination of miniature set according to IR System methods.

Having thus determined the regional boundaries the lamps are set up to produce the desired key and modelling lighting for each region with minimum spillover into adjacent regions and reasonably good blending of lighting between regions. As a general rule this will merely require inserting the plug at the end of each lamp cable into a spider corresponding to the region which that lamp will illuminate. The power supply and adjunct wiring to the spider are of course properly associated with the power supply to the camera motor, both as to frequency and phase.

The camera is set up at its appropriate location and checked, by means of the finder, for focus and depth of field. It may be added that the finder should preferably also be adapted to IR System viewing so that the cameraman has a correct idea of the depth of field in the corresponding picture.

In the event that background projection is used, it becomes necessary to time the projection of the background so that it corresponds with the regional location of the projection screen. Otherwise stated the light-source in the projection lamp house has a phase and duration appropriate to the region in which the screen is located. Thus the background image is in complete focus thereby avoiding one of the most serious limitations in such composite pictures, namely, the conflict in focusing, so to speak, between the actors in the foreground and the screen in the background.

Experiments have been carried out to judge the amount of spillover light which is permissible. Experience has shown that the sharpness of photographic focus is not appreciably affected on important parts of each regional picture if the spillover does not exceed 3 per cent. On the most important planes it is usually preferred to keep the total spillover at 2 per cent or less.

Extensive work with the IR System has made clear that the method is not a mathematical abstraction or a precision geometrical system under normal working conditions. It turns out to be a convenient method of operation with which liberties can be taken in practice and which can be used with the same latitude and discretion as any other photographic system. When first utilized, it is found strange to accept the IR System convention that light can not be poured through the set passing through one region after another but that the illumination must rather be handled sequentially and region-wise, so to speak. The duplication of the existing lighting effects by modifying lamp locations and directions seems at first unfamiliar.

However, after a little experience with the system all strangeness disappears and the simplicity of operation of the system becomes evident.

Some semi-laboratory set-ups of equipment and the results obtained with them will next be considered. In Fig. 8 is shown an arrangement for IR System photography on a miniature set, using flashing gas-filled lamps. The motion picture camera is mounted on the small table to the left together with a monitoring finder arranged for IR System operation and a group of timers whereby the flashing of any regional lighting can be timed as desired. These units are synchronously driven and may be either combined or separated as desired. Suspended from the large central framework is a group of tubular lamps each of which, by the use of a suitable reflector, is arranged to illuminate appreciably only a single region. On the table under the framework, in the field of the camera, is a group of test-charts which can be readily moved to any desired position and which form a convenient subject for test photography. Mounted on the framework to the right is a group of power-supply units for the lamps, one power unit being provided for each region. These units are essentially high-voltage rectifiers charging condensers which, in turn, discharge through the gas lamps when these are suitably triggered. Simple methods of triggering the lamps without mechanical or electrical complications were devised. The timing of the lamps (that is, the triggering impulses) was derived from the regional timer synchronized with the camera operation as referred to above. The camera, as well as the finder, each contained a diffo. It was interesting in working with this equipment to be able to focus each region of of the set independently by shifting the timing of the corresponding regional illumination, this obviously being a startling and unprecedented procedure.

In Fig. 9 is shown an enlargement of a single frame of 35-mm film. A 50-mm lens operating at approximately $f/2.2$ was used. The foreground toys were 5 feet from the lens; the background toys 15 feet. The toys were placed on a checkered fabric which also formed the background. The depth of the set corresponded to approximately 5 regions. Fig. 9 illustrates the result obtained with standard photography. The toys in the second region are obviously not in sharp focus and the background is unidentifiable.

In Fig. 10, on the other hand, are shown the results obtained by IR System photography using flashing gas lamps on identically the

FIG. 9. Enlargement of 35-mm frame with ordinary photography of miniature set. *F* 50-mm *f*/2.2; foreground 5 feet, background 10 feet.

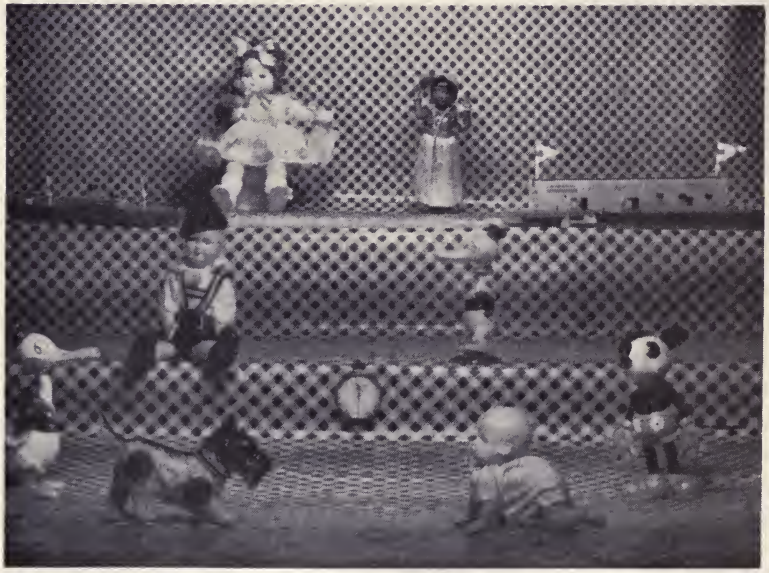

FIG. 10. Enlargement of 35-mm frame with IR System of photography of miniature set. Same lens, aperture, film, development, and enlargement as for Fig. 9.

same set. Needless to say the same lens, aperture, film, development, and enlargement ratio were used in Figs. 9 and 10.

Fig. 11 illustrates a small set illuminated according to the IR System by means of shuttered incandescent lamps. As a matter of convenience, these lamps were mounted on pipe racks. The shutter of each lamp was regionally synchronized and operated in synchronism and suitable phase relation to the camera and diffo drive. It was also possible to take pictures according to standard photography on this set-up either by removing the diffo from the camera or by

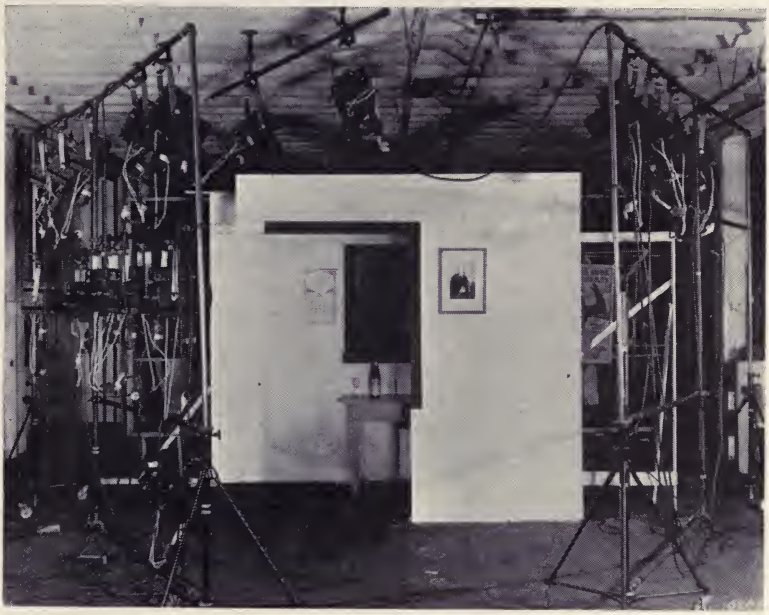

FIG. 11. Shuttered incandescent-lamp illumination arrangement of set according to IR System.

bringing all regional illuminations into the same timing (for example, that of Region 1).

Using a lens of 2-inch focal length operated at $f/2$, pictures were taken by standard photographic methods with four men between approximately 7 feet and 25 feet from the camera. The result is shown in Fig. 12. Only the foreground individual is in focus. The calendars in the middle ground should be noted, and are obviously badly out of focus. The poster behind the man in the background is indistinguishable.

Fig. 13 shows the corresponding result when IR System operation was utilized. The same lamps, lens, aperture, film, development, enlargement, and all other pertinent circumstances apply to both Figs. 12 and 13. The appearance of the calendars and poster should again be noted.

A somewhat quantitative comparison between standard photography and IR System photography is shown in Figs. 14 and 15, respectively. Like Figs. 12 and 13, these are enlargements of single frames of 35-mm film. In each case the foreground plane was approximately 11 feet in front of the right-hand calendar. The left-hand calendar was approximately 15 feet from the lens, and the background poster at 25 feet from the lens. These pictures represent the empty set corresponding to Figs. 12 and 13, *i. e.*, with the persons absent. Close microscopic examination failed to detect any difference between the sharpness of the test-charts in Fig. 15 at various distances.

8. MULTIPLE SIMULTANEOUS ANGLE SHOTS

Using systems wherein relatively brief flashes of timed illumination are employed in each part of the set, it is possible to photograph the same subject matter "simultaneously" from different angles. It is true that different portions of each frame period of 1/24th of a second are used for the photography of each angle shot but the final films give no indication of this slight time staggering between the various angle shots. The method can be illustrated by consideration of Figs. 16 and 17.

In the upper portion of Fig. 16 is shown one method of time division between two cameras. The periods during which the shutter of each camera is open, and the periods during which it is closed are indicated. Consider the period shown to the left during which the shutters are open. The length of this period may be taken as 1/48th of a second on the arbitrary assumption that a 180-degree shutter is used. This period of 1/48th of a second is equally divided by the vertical dot-dash line. The period of 1/96th of a second to the left of the dividing line is assigned to Camera 1. Assuming 5-divisional operation, the flashes in the respective divisions occur as indicated by the vertical lines which are designated, respectively, *F11–F15*. The period of 1/96th of a second to the right of the dividing line is assigned to Camera 2 Assuming this also to be a 5-divisional take, the divisional light flashes will occur as indicated by the vertical lines *F21–F25*. So far as photography is concerned the arrangement thus

FIG. 12. Enlargement of 35-mm frame with ordinary photography of set. *F* 2 inches *f*/2; men, respectively, at 7 feet 6 inches and approximately 11, 15, and 25 feet.

FIG. 13. Enlargement of 35-mm frame with IR System photography of set. Same distances, lamps, lens, aperture, film, development, and enlargement as in Fig. 12.

FIG. 14. Empty set corresponding to conditions of Fig. 12; ordinary photography.

FIG. 15. Empty set corresponding to conditions of Fig. 13; IR System photography.

far described is adequate and enables the simultaneous photography by the IR System of two different angle shots photographed, respectively, by Cameras 1 and 2. However, there would be only 24 flashes per second on each portion of the set using this arrangement, and this would give rise to noticeable flicker. To minimize or eliminate this flicker, additional flashes *A F11–A F15* and *A F21–A F25* are introduced as shown during the period when the shutters of the two cameras are closed. While these additional flashes do not produce any photo-

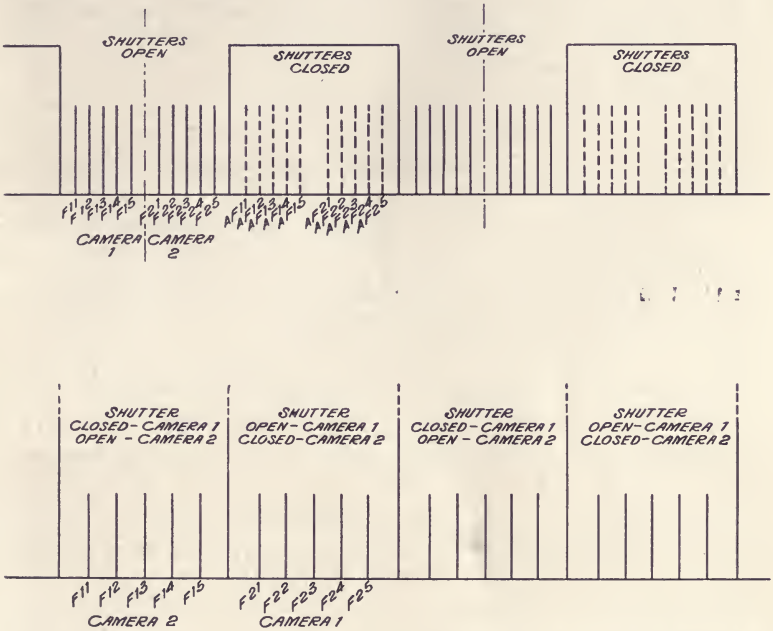

FIG. 16. Illumination time division for simultaneous multiple-angle photography in IR System.

graphic effect they do minimize flicker since there are now 48 flashes per second illuminating each portion of the set.

An alternative arrangement of somewhat different type is shown in the lower portion of Fig. 16. In this case the two cameras are so operated that when the shutter of one is open and the set is illuminated, the shutter of the other is closed and the set is not illuminated by its associated lights. The divisional illuminations for Camera 2 are here indicated by *F11–F15*, while those for Camera 1 are shown as *F21–F25*. The avoidance of flicker in this arrangement requires

some planning in the placement and use of light, and for this reason the arrangement shown in the upper portion of Fig. 16 will sometimes be preferred. Experiments showed the feasibility of operation according to the methods of Fig. 16 whereby several cameras are each associated with their timed illumination of the set, and with the divisional light distribution utilized in the IR System.

A schematic layout for the lights corresponding to the arrangements of Fig. 16 is shown in Fig. 17. The three-walled set is indicated. Camera 1 takes a comparatively wide-angle shot wherein the person *C*, who is the center of interest, is photographed in a semi-close-up.

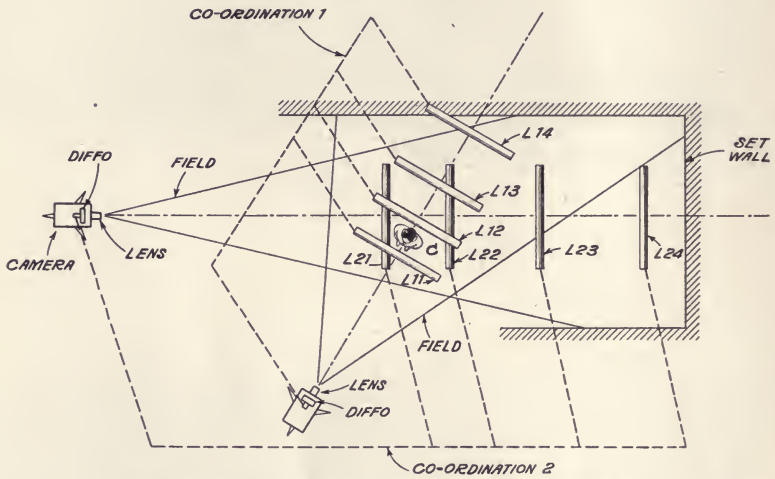

FIG. 17. Illumination and camera arrangements for simultaneous multiple-angle shots according to IR System.

The illumination is produced by the divisional lamps *L11–L14*. Since this is to be a semi-close-up, the illumination may be kept comparatively soft. The lamps are coördinated with the camera and diffo as indicated by the dashed lines marked *Co-ordination 1*. Camera 2 takes a longer shot but with a narrower angle of a different section of the set as well as a partial side view of the individual *C*. Since this is a more distant view, the lighting may be made harder to emphasize detail and modelling. The corresponding lamps are *L21–L24*. In this case also, the lamps are timed in association with the camera and diffo as indicated by the dashed lines marked *Co-ordination 2*. It should be particularly noted that entirely different lighting effects

can be produced in the pictures taken simultaneously by the two cameras—a markedly novel and obviously useful feature.

9. STUDIO LIGHTING METHODS FOR INCREASED-RANGE SYSTEM

In essence, conventional studio lighting may be arbitrarily divided into key lighting and modelling lighting. The former is a more or less general illumination, intended to set a minimal lighting level through all or most of the set. The latter is lighting which is intended to produce shading, thus giving roundness, form, or solidity to persons or objects. It is generally carefully directed and of the spot variety.

In the IR System, modelling lighting requires relatively little change from the previously used conventional methods. Some care is taken to use a sufficient number of aimed spots to avoid undue space spillover while yet retaining the desired modelling for rather wide axial excursions of the actors. In the frontal regions this requires reasonable care. In the rear regions the latitude in light placement is so wide as to eliminate any necessity for special treatment.

Key lighting by the IR System requires suitable methods for duplicating the lighting vector in any important portion of the set. That is, the intensity and direction of the incident light must be duplicated in each region, and without undue space spillover of light from that region. It has been found in practice that any desired light vector normally encountered in motion picture photography can be duplicated by IR System lighting after a brief analysis of what is required. As experience in the use of the IR System is acquired, this duplication becomes increasingly simple. The details of light placement and the securing of specific effects using IR System lighting can not be here included. To some extent, as with all other lighting, it involves solving minor lighting problems as one goes along.

10. PRESENT OPERATING CONSIDERATIONS

The following comments list certain minor limitations in the IR System which, in the main, are only apparent. Methods of overcoming these seeming restrictions are known, except where otherwise stated.

(*a*) *Need for Controllable Lighting.*—Since the regional or divisional control of lighting is an essential feature of the IR System it is obvious that the system can be best used under studio conditions. The evolution of modern light-sources makes their control practicable.

(*b*) *Registration Effects.*—The magnitude of the registration

effects is controllable, and all indications are that such effects can be made pictorially imperceptible or negligible. A number of comparatively simple equipment designs and operational methods have been devised for this purpose.

(*c*) *Lighting Efficiency.*—The lighting efficiency of the IR System depends upon the type of lamp which is used. Flashing lamps, wherein all radiated light is emitted during an extremely brief period, enable efficient operation. If arcs or incandescent lamps are used, with suitable shutter arrangements, the total amount of light produced by each lamp must be correspondingly greater than that which passes through the shutter opening to the related region or division of the set. The shutter naturally prevents the utilization of the light not passing through its opening. Thus, for shuttered lamps, while the amount of light on the actors does not exceed that used in ordinary photography, the total amount of light flux produced by the lamp (and consequently the power load and the studio air-conditioning load) must be increased. On the other hand, when flashing lamps (*e. g.*, gas lamps) are used, and provided these have the high efficiency of the better designs of this type of lamp, the light on the actors and also the total light flux produced by the lamps are each no greater than for usual photography. Thus the flashing lamp, although the more unusual, is in some respects more convenient and efficient.

(*d*) *Flicker.*—Inasmuch as the illumination is intermittent, precautions are taken to prevent visible or objectionable flicker. In Fig. 16, a 48-flash-per-second regime was illustrated. However, the lighting frequency on each portion of the set can be increased as desired. Experience has shown that 48-cycle illumination, while not absolutely smooth, does not seem to create sufficient flicker to be annoying to most people.

(*e*) *Acoustic Interference.*—Shutters, driving motors, or any other equipment for intermittent illumination timing must be silenced to an extent such that no sound from them is recorded. The expedients adopted for this purpose are in considerable measure conventional.

(*f*) *Inductive Interference.*—Flashing lamps, and their associated timing circuits, require suitable electrical design and shielding to avoid any undesired induction, for example, into the recording circuits.

(*g*) *Approach Shots.*—The maintenance of sharp focus in all parts of the set throughout approach shots is readily possible in the IR System. It requires the use of one of a number of expedients mainly based on a consideration of appropriate regional and divisional ar-

rangement of the lighting. The detailed methods can not be included within the space of this paper.

(*h*) *Panoramic Shots.*—It is also possible readily to make panoramic shots using the IR System, the lighting arrangements suitable for the purpose being known and practicable. Experience and analysis have shown that the adaptation of regional illumination to a wide variety of photographic procedures is simpler than might be anticipated.

11. FUTURE DEVELOPMENTS

While the IR System is inherently an optical development, it is believed that it will have profound effects on the dramatic and pictorial results to be obtained in the fields of still-picture advertising and the like, on entertainment and educational motion pictures, on television, and on a number of related fields. Dramatically, it should enable a gradual blending of the arts of the legitimate theater and the motion picture studio, as a result of which the motion picture will gain added continuity, fluidity, smoothness, and naturalness, all of which should add to its appeal. Further, the dramatic freedom of the actor will be enhanced, and the reduction in shooting time will reduce the strain on him. The matching of acting in all parts of a prolonged sequence will be more nearly automatic and perfect, as will be the matching of the sound with the picture in all parts of a take.

12. CONCLUSION

In relation to the work described in this paper it is a pleasure to acknowledge the capable coöperation of certain of my co-inventors and associates. In particular, I am indebted to Mr. Harry R. Menefee for the many original and useful thoughts as well as practical constructions which he has contributed, to Mr. Fritz Kastilan for the elaborate optical calculations and the careful designs which he originated, and to Messrs. Bernon Woodle and Remsen Donald for their painstaking calculations and laboratory activities during the progress of the work. And I am especially indebted to Mr. Courtland Smith for the inspiration, thoughtful executive planning, and courage which he has constantly displayed and which have made possible the prosecution of this project as well as its successful outcome.

A NEW DICHROIC REFLECTOR AND ITS APPLICATION TO PROTOCELL MONITORING SYSTEMS*

G. L. DIMMICK**

Summary.—*Certain crystals have long been known to transmit light of one color and reflect light of another color. Some thin metallic films also exhibit the same phenomena. By evaporating alternate layers of high and low-index insulators on glass, it is possible to produce a surface having predetermined transmission and reflection characteristics, and having no appreciable absorption. A method of determining the properties of multilayer films is described.*

Design details and curves are given for a three-layer film having its peak transmission at 4400 A and its peak reflection at 7920 A. This film is successfully employed in high-level photocell monitoring systems for sound recorders. Nearly all the actinic value of the modulated light is transmitted to the photographic film while a large part of the red and infrared is reflected to a cesium photocell for monitoring.

It has long been known that thin films of some metals are selective in their ability to reflect and transmit light. A thin film of gold is quite transparent to green light and shows strong selective reflection for the red and yellow region. Many aniline dyes appear to have one color when viewed by reflected light and another color when viewed by transmitted light. The material possesses what is known as a surface color, and the transmitted light gets its color by being deprived of certain rays by reflection at the surface and certain others by absorption in the interior.

There is another type of selective reflector which depends upon the interference of light in thin films. This type is far more efficient because the absorption is usually negligible. In its simplest form this reflector consists of a single thin film between two transparent media. A soap bubble and a layer of oil on water are perhaps the most commonly experienced examples of this type.

If we wished to make use of the interference principle to obtain a selective reflector capable of reflecting a large percentage of light in a narrow region of the spectrum, we should find that the single thin

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film would be inadequate for the purpose. Both the intensity and the purity of the reflected light may be increased through the use of multiple films arranged in alternate layers having different indices of refraction. As is often the case nature has already accomplished this result and with a remarkable degree of precision. Crystals of chlorate of potash are sometimes found to reflect very brilliant and pure colors. In 1852 Sir George Stokes investigated this phenomenon and found it to be due to the existence of planes within the crystal at which periodic "twinning" had occurred. Later, in 1888 Lord Rayleigh studied these crystals and found that the spectrum of the reflected light consisted of a narrow band only about twice the width of the D lines. From this he calculated that a crystal plate 0.14 mm in thickness contained about 700 reflecting planes.

Thin films of many metals and dielectrics may be produced by heating the materials in a vacuum and allowing the vapor to deposit upon a plate of glass. This very important process has been known for a long time, but it is only in the last few years that it has received the attention which it deserves. Dr. J. Strong did important work[1] in applying the evaporation method to the production of aluminum films for mirrors. Later he evaporated thin films of calcium fluoride on glass and observed a considerable reduction in the surface reflection. In 1939 Dr. C. H. Cartwright worked on the problem at the Massachusetts Institute of Technology. He not only improved the process of reducing reflection from glass but also produced selective reflectors by evaporating multiple films on glass.[2] The author's interest in the subject began when he visited Dr. Cartwright and saw some of his work.

A rigorous mathematical analysis of multiple films would be quite involved and would not be of any help in giving us a physical picture of what happens within the films to produce the final result. The graphical method of analysis is far more flexible and is the one that the author has made use of in the design of a selective reflector having predetermined characteristics. Although the method described below is not strictly accurate, it yields a result which is consistent with our meager knowledge of the optical constants of evaporated materials.

Fig. 1(a) shows a film having a refractive index of 1.222 on the surface of a glass plate having a refractive index of 1.500. A ray of light A_0 is passed through the film from the glass plate into the air. The primary reflections from the two surfaces are shown as A_1 and

A_2. The amplitudes of the two reflected rays are determined from the formula

$$A_1 = \frac{\frac{N_0}{N_1} - 1}{\frac{N_0}{N_1} + 1} \qquad \text{and} \qquad A_2 = \frac{\frac{N_1}{N_2} - 1}{\frac{N_1}{N_2} + 1} \tag{1}$$

These expressions for the amplitudes of the reflected rays are quite accurate when the angle of incidence of A_0 is less than 30 degrees.

Fig. 1(*b*) shows the graphical method of determining the resultant amplitude A_r of the two reflections. The lengths of the vectors A_1 and A_2 are laid off in proportion to the calculated values. The vector A_1 is stationary and positive in sign.

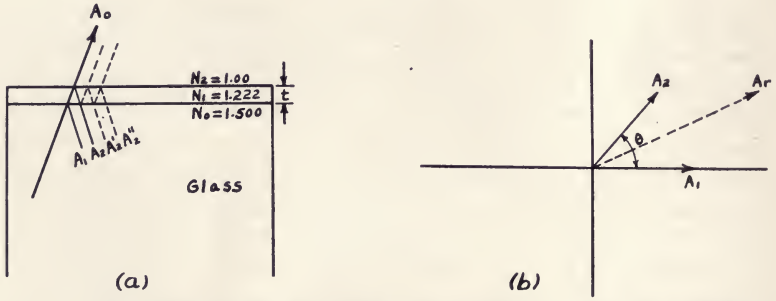

FIG. 1. (*a*) shows a single low index film on glass. (*b*) shows the arrangement of vectors for the film in Fig. 1(*a*).

The vector A_2 coincides with A_1 when the film thickness is zero, and rotates in a counterclockwise direction as the film thickness increases. The angle between the vectors is determined from the equation

$$\theta = \frac{4\pi}{\lambda} N_1 t \tag{2}$$

where λ is the wavelength of the light and t is the film thickness. Thus when $N_1 t = \lambda/4$, then $\theta = \pi$ radians, or 180 degrees. The vectors are opposed in direction and equal in amplitude, making the resultant reflection zero for a particular wavelength of light. If $N_1 t$ has other values than $\lambda/4$ or multiples of it, the resultant amplitude A_r is determined graphically by the parallelogram method and the reflectivity is obtained from the relation

$$R = \left(\frac{A_r}{A_0}\right)^2 \qquad (3)$$

where A_0 is the amplitude of the incident light.

Suppose the film is made to have an optical thickness of $\lambda/4$ at 5100 A and our problem is to determine the curve of reflection *vs.* wavelength between the limits of 4000 and 7000 A. Fig. 2(*a*) shows the angular position of vector A_2 for different wavelengths. The angle between A_1 and A_2 for any wavelength is given by the expression

$$\theta = \frac{5100}{\lambda} \times 180 \qquad (4)$$

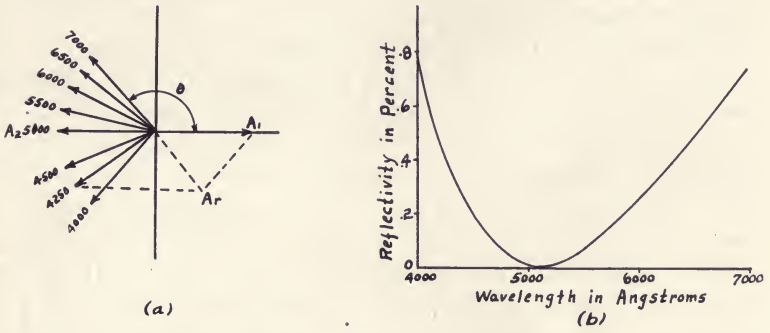

Fig. 2. (*a*) shows the arrangement of vectors for different wavelengths. (*b*) shows the relationship between per cent reflectivity and wavelength for the single film in Fig. 1(*a*).

Thus for 7000 A the angle is 131 degrees and for 4000 A the angle is 229 degrees. For each wavelength the vectors A_1 and A_2 are added graphically and the resultant amplitude A_r is squared to obtain the reflected intensity. Fig. 2(*b*) shows how the reflectivity varies with wavelength when the optical thickness of the film is $\lambda/4$ at 5100 A.

In arriving at this curve it will be observed that no account was taken of the change in index of refraction with wavelength for the glass plate or the film. If we knew the index of refraction at different wavelengths for both these materials, it would be quite easy to take this factor into account. In Fig. 3 the vectors A_2 and A_1 would have different amplitudes for each wavelength instead of having a constant amplitude as shown. For each wavelength the amplitude would be determined from the relations of equations *1*. If the dispersion is no greater than the value for ordinary crown glass,

our maximum error would not be more than 6 per cent if we disregarded it.

In addition to the primary reflected ray A_2 in Fig. 1(*a*), there exists secondary and tertiary rays A'_2 and A''_2, shown as dotted lines. The effect of these rays also can be included in the graphical method. The vector A'_2 would be drawn one-hundredth as long as A_2 and its angle of rotation would always be made just twice that of A_2. The vector A''_2 would be one ten-thousandth as long as A_2 and its angle of rotation would always be made just three times that of A_2. All the vectors would be added graphically in order to determine the resultant amplitude under any given condition. It can be seen that if the individual primary reflections are relatively small, the effect of secondary and tertiary reflections is negligible.

The analysis of the single film on glass has been made in order to illustrate the ease with which the properties of thin films can be determined by the graphical method. We shall now make use of the method to design a multifilm selective reflector to meet a given set of practical conditions. When completed, the reflector is to be placed in the light path of a sound-recording optical system between the slit and the objective lens. Its purpose is to transmit most of the actinic rays of light required to expose positive film and to reflect a large part of the red and infrared light to a cesium photocell for monitoring purposes. The advantages of such a mirror are obvious. It permits us to have a high-level monitoring system relatively free from hiss, microphonic disturbances, and noise due to electrostatic or magnetic pick-up. It maintains a rigid check upon the quality of the modulated light reaching the film, without appreciable reduction in exposure.

Ordinary positive film receives its greatest exposure from an incandescent lamp at about 4400 A. A cesium photocell receives its greatest energy from an incandescent lamp at about 7500 A. Our requirements for the selective reflector are that its peak transmission occur at 4400 A and its peak reflection occur at 7500 A. We shall try a three-layer film to see whether it meets these requirements. Fig. 3(*a*) shows a plate of glass with two high-index films and one low-index film upon its surface.

The deciding factor in choosing values for N_2, N_3, and N_4 (Fig. 3*a*) was that materials are available that have these indices of refraction. In order to obtain the greatest peak transmission at one wavelength and the greatest peak reflection at another wavelength, it is necessary

so to arrange the films that the algebraic sum of the four reflected amplitudes is as great as possible and that the algebraic sum of one group of amplitudes is equal to the sum of the remaining amplitudes. The first condition is obtained by placing the high-index film on the outside in contact with the air. When the glass plate is made to have an index of refraction of 1.545, the second condition is also met. In other words, $A_1 + A_2 + A_3 + A_4$ is greater than for any other possible arrangement of the three films, and $A_1 + A_4 = A_2 + A_3$.

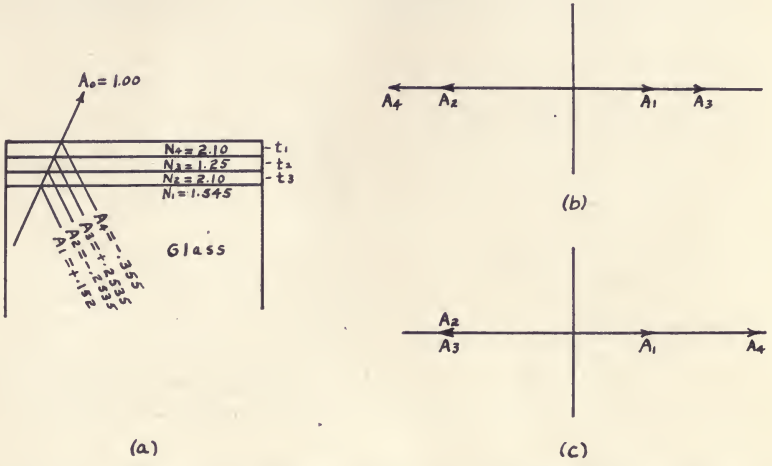

FIG. 3. (*a*) shows a 3-layer film on glass. (*b*) shows the arrangement of vectors for zero film thickness. (*c*) shows the required arrangement of vectors at 4400 angstroms.

The next problem is to determine the proper thicknesses for the three films. Fig. 3(*b*) shows the arrangement of the vectors when the thickness of all films approaches zero. The vectors resulting from light reflected in passing from a medium of higher to a medium of lower index are given one sign. The vectors resulting from light reflected in passing from a medium of lower to a medium of higher index are given the opposite sign. The reason for this is that a phase reversal takes place when light passes from a dense to a rare medium but there is no phase change when it passes from a rare to a dense medium. The author prefers always to give the stationary vector A_1 a positive sign and let the above considerations determine the signs of the other vectors.

Fig. 3(*c*) shows the necessary arrangement of the vectors at 4400 A if the transmission is to be maximum. Comparison of Figs. 3(*b*) and 3(*c*) shows that vector A_2 has been rotated through 2π radians, or an even multiple of this angle. Since the optical thickness $N_1t_1 = \theta\lambda/4\pi$, it follows that the minimum thickness of the first film is $\lambda/2$. Again comparing Fig. 3(*b*) and Fig. 3(*c*), it is evident that vector A_3 has been rotated through an odd multiple of π radians. But the first film has already caused A_3 to rotate through 2π radians. The first odd multiple will then be 3π radians, and this makes the optical thickness of the first two layers $3\lambda/4$ and the optical thickness of the

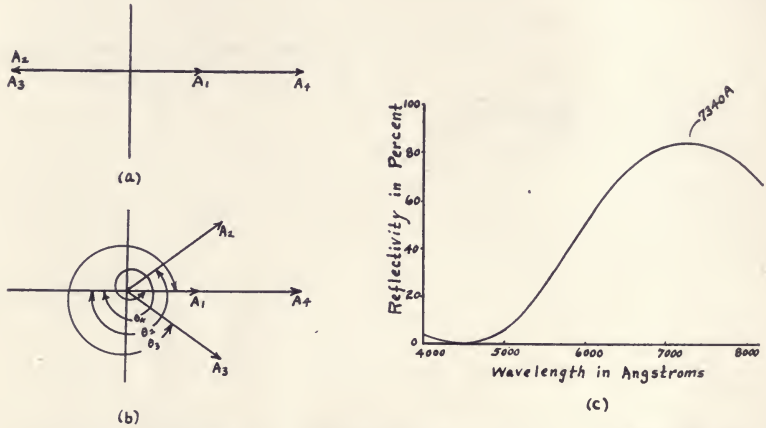

FIG. 4. (*a*) shows the arrangement of vectors at 4400 angstroms. (*b*) shows the arrangement of vectors at 7340 angstroms. (*c*) shows the relationship between per cent reflectivity and wavelength for the selective reflector.

second layer $\lambda/4$. A final comparison of Fig. 3(*b*) and Fig. 3(*c*) shows that vector A_4 has been rotated through an odd multiple of π radians. The first two films have already rotated A_4 through 3π radians, so the first odd multiple will be 5π radians. This corresponds to an optical thickness of $5\lambda/4$ for all three films or $\lambda/2$ for the third film. This completes the design of the three-layer selective reflector.

We now have to find out whether this reflector meets our requirements. To do so we lay out the positions of the four vectors for several different wavelengths and find the resultant amplitude in each case. The square of the resultant amplitude gives us the reflected intensity for the wavelength in question.

Fig. 4(*a*) shows the position of the four vectors for a wavelength of 4400 A and Fig. 4(*b*) shows their position for a wavelength of 7340 A. The angular positions θ_2, θ_3, and θ_4 of the vectors A_2, A_3, and A_4 (Fig. 4*b*) are determined for any wavelength by the formulas

$$\theta_2 = \frac{4400}{\lambda} \times 360° \qquad \theta_3 = \frac{4400}{\lambda} \times 540° \qquad \theta_4 = \frac{4400}{\lambda} \times 900°$$

where λ is the wavelength in question and θ is the angle of a particular vector as measured from its position shown in Fig. 3(*b*). This is the position when the film thicknesses approach zero, but it also represents the position when the wavelength approaches infinity.

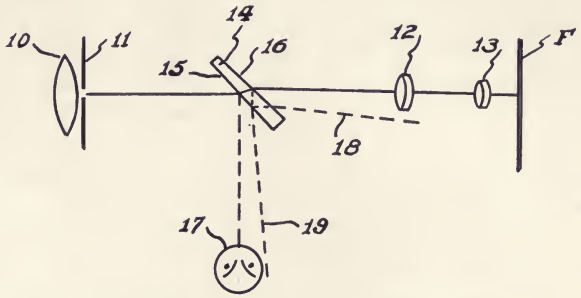

Fig. 5. Shows the position of the reflector in a standard recording optical system.

Fig. 4(*c*) shows a curve of reflectivity *vs.* wavelength for the three-layer selective reflector (Fig. 3*a*) as determined by the graphical method. According to this curve the transmission of the reflector is 100 per cent at 4400 A and the reflectivity is 84 per cent at 7340 A. Because of the assumptions that have been made, it is not to be expected that the actual reflector will reach values quite as high as indicated above. Measurements were taken on many reflectors made to the above specifications. These showed that the transmission is 95 per cent, when measured with a filter and photocell having the same color characteristics as positive film. The reflectivity as measured through a Wratten *A* filter is 65 per cent. In view of the rather broad band width of these filters, it is felt that the measurements represent a reasonably good confirmation of the theory.

Photocell monitoring systems utilizing the new selective reflectors have been in use in two Hollywood studios for several months. The reflectors were inserted into the objective barrels of standard vari-

able-density and variable-area optical systems as shown in Fig. 5. The three-layer film was applied to the bottom surface of a glass wedge *14* which was placed at a 45-degree angle in the optical path between the slit *11* and the objective lens *12* and *13*. A photocell *17* was placed directly beneath the reflector. Several lenses (not shown) between the reflector and the photocell serve to direct the light from the slit upon the two push-pull cathodes. The angle and the thickness of the wedge *14* were such as to cause no displacement of the light-beam at the back of the objective *12* when the reflector is inserted in a standard optical system. The angle of the wedge is just sufficient to cause the light *18* and *19*, reflected from the upper surface *16*, to be thrown off the edge of the objective lens and the photocell. This results in the practical equivalent of a single-surface reflector, and completely eliminates the double image of the slit that would result if the two faces *15* and *16* were parallel.

REFERENCES

[1] STRONG, J.: "On a Method of Decreasing the Reflection from Non-Metallic Substances," *J. Opt. Soc. Amer.*, **2b** (Jan., 1936), p. 73.

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PRODUCTION AND RELEASE APPLICATIONS OF FINE-GRAIN FILMS FOR VARIABLE-DENSITY SOUND RECORDING*

C. R. DAILY AND I. M. CHAMBERS**

Summary.—*Fine-grain film materials have supplanted the normal positive type emulsions for all variable-density sound-recording and printing operations. The sound-quality improvement realized by the reduction in noise and distortion is now available for all sound operations, including release prints. The paper describes a number of problems encountered and solved in the commercial application of such films for sound recording, including factors affecting the choice of negative and print materials, noise, distortion, sensitometric characteristics, recorder lamp supplies, and noise problems on stages.*

A complete fine-grain sound-recording program is now in operation at this Studio for variable-density sound-track, a fine-grain negative stock being used for all production and release and a fine-grain positive stock for all dubbing prints and black-and-white release prints. Daily sound prints are also made on the out-take fine-grain negative stock. This improved film-recording and release program has been in operation since March, 1941, and represents the culmination of over three years of work on the general problem of adapting fine-grain films for sound recording and release picture and sound use. Over two years ago an earlier type of fine-grain film was first used on a large scale for sound dubbing prints and later the same film was used for a limited amount of release negative and release printing,[1] while now the improved films are used for all operations. While a substantial improvement in sound quality has been the major objective of this project, a gratifying benefit to the release picture quality has also been obtained. The presentation of orchestral and vocal music has been materially improved in clarity and definition due to the increased volume range made available. "Swish" is no longer a major source of trouble, permitting piano, guitar, drum, and similar

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** Paramount Pictures, Inc., Hollywood, Calif.

types of percussion instrumentation to be presented with improved fidelity. Dialog quality has also been improved, voices standing out with better screen presence, an important factor in release to the theaters. Film distortion has been reduced due to (*a*) improved methods of development, (*b*) the characteristics of the film stocks themselves, and (*c*) to the use of ultraviolet light for printing. Processing latitudes are also wider than formerly obtained and the high-frequency response has been increased due to the improved resolution of the film.

Some of the problems encountered and solved in connection with the commercial application of these new films will be described in this paper. Messrs. Wilkinson and Eich[2] describe the laboratory modifications and procedures in connection with the development and printing of such films for release.

At the Fall Convention of the Society in October, 1939, a paper[1] was presented describing methods employed at that time in connection with the first commercial release application of fine-grain film stocks. The experience gained in connection with these first releases had clearly indicated that a marked reduction in film noise would be accompanied by an improvement in sound quality, and the recent large-scale use of the new fine-grain films has completely verified this earlier observation.

The fine-grain negative and print stocks currently used for sound recording represent a definite improvement over the types of fine-grain films available two years ago. This improvement has been obtained through the testing of a series of experimental film stocks, to determine their adaptability to the numerous production requirements. Since the desired characteristics of the sound negative stock are dependent to some extent upon the characteristics of the release positive to be used, it was first necessary to obtain a fine-grain release positive stock which would satisfy picture requirements. When such a satisfactory stock for picture release became available during the latter part of 1940 the Laboratory undertook the modification of the daily and release printers to provide the necessary increase in light. Since it was also known that sound quality would be further improved by the use of ultraviolet light in the printing to the fine-grain stock, sufficient light-intensity was made available in the printer modification to permit sound printing with a 2-mm Corning *584* filter. This fine-grain release positive material makes possible a static reduction of 6 to 8 db in film noise and a swish reduction of 10

to 15 db in the release to theaters compared with the former standard release print stocks. While a still finer grained stock would be desirable, the benefits obtained from this stock are definitely worth while and valuable experience is being gained in the handling of such materials.

At approximately the same time that the fine-grain release positive material became available, a suitable fine-grain negative also was developed which could be printed to the release positive material with a further improvement in sound quality, and with an added increase in signal-to-noise ratio because of the added reduction in negative noise. This new negative material is essentially as fine-grained as the new release positive and also possesses satisfactory development characteristics when exposed with tungsten light on the existing production recorders.

Tungsten recording was considered necessary for the production recorders because of the added weight and power-supply problems which would have to be met if arc sources were used, particularly for location work. It was found possible to obtain sufficient density on the new negative stock with a tungsten lamp by taking advantage of (*a*) high-gamma negative development for use with ultraviolet printing, (*b*) a modification of the negative developer to give the highest density consistent with stable development practice and low distortion, and (*c*) by coating the lens surfaces of the recorder optical system.

The new negative stock is also suitable for pre-selection sound printing, an important requirement in connection with the negative pre-selection practice employed. All sound negative takes are broken down into two groups at the end of each day's work. The "O.K." takes that are to be printed are spliced together and sent to the Laboratory for immediate development, while the exposed "out" takes and non-exposed short ends are spliced together in a second group and held undeveloped. These "out" takes are identified so that any one of them can be readily located and developed at a later date if needed by the Production Department. Since takes may have to be developed days or weeks after they are recorded, it is desirable that minimum changes in characteristics be experienced during this time, such as loss of density and change of gamma. The new negative stock is quite satisfactory in this respect, based on a six-month use.

When a production is completed, the "out" takes are sent to the Laboratory to be used for daily sound print stock. Since the new

negative stock is essentially as fine grained as the fine-grain positive, the daily prints are very quiet and their quality is comparable to the dubbing prints made on the fine-grain positive. The same positive developer and the same type of ultraviolet printing light is used as for release printing, with only a slight difference in exposure.

The splicing of the takes of negative stock for either negative development or for subsequent daily print use is accomplished satisfactorily by scraping both sides of the film, cementing with normal Roscoe cement and allowing a 15-second drying time. The splices in the takes to be developed as a negative are further reinforced by using Eastman film splicing tape, as it is very important to prevent these splices from pulling apart in the negative developer. Since the current splicing and reinforcing technic was adopted over four months ago, there has been no breakage of film in the negative developer.

A transition period of a few weeks' duration was necessary to convert the plant completely from the use of standard negative to fine-grain negative, involving changes in both the printing and negative development procedure. Since the fine-grain negatives required ultraviolet prints while the standard negatives formerly used required white-light prints, it would have been impracticable to use both types of negatives on a given production without unduly complicating the dubbing print operation which is normally made from assembled reels of production negative. Therefore, when the plant was ready to start recording fine-grain negatives, new productions were started on the new stock while productions which were then being recorded on standard negative were continued in this manner to completion. The new negative stock could be developed in the same tank with the then current standard negative stock, effecting a definite economy in film handling during the transition period.

Both the new fine-grain materials are quite hard and appear to be less susceptible to dirt pick-up than the older types of emulsions. This relative freedom from dirt and noise trouble is quite essential with fine-grain films because the reduction in film noise uncovers dirt noises that formerly would have been less important because of the masking effects of the film noise itself. While additional care is taken, the negatives stand up well during the cutting, cleaning, and printing operations; the positive material is giving satisfactory service in release.

In order to increase the light-transmission efficiency of the produc-

tion sound recorders, their condenser and objective lenses were given a special surface treatment to reduce the amount of reflected light.[3] This coating, which was applied to give the highest transmission at 4400 A, increased the efficiency of the recorder optical systems by approximately 50 per cent permitting the 9-ampere, 10-volt lamps to be operated at 8.5 instead of 9.0 amperes. Thus a safe margin of exposure was available to take care of variations in lamp and stock sensitivity.

The release recorders are equipped with an auxiliary optical system to permit squeeze-track recording, and require approximately 40 per cent more light than the production recorders. In order to provide a safe margin of increased light-intensity on these machines, the tungsten lamps were replaced with air-cooled *AH-8* high-pressure mercury arcs, in addition to coating the lenses. Since satisfactory operation of such arcs has been obtained with the temporary arc installation used two years ago,[1] the power and air-supply systems for the arcs were completely redesigned further to improve their operation.

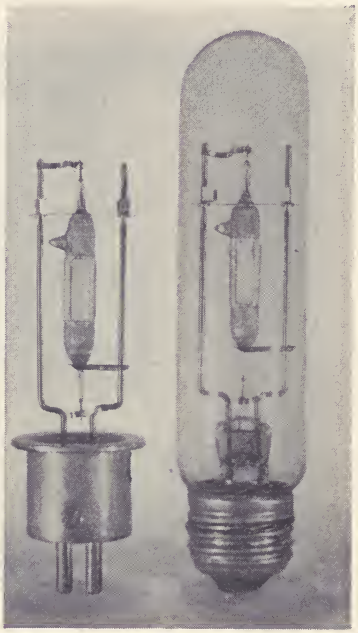

FIG. 1. High-pressure *AH-8* mercury arcs. (*Left*) modified arc, mounted in special socket; (*right*) unmodified arc.

The arc itself was remounted in a new holder to permit rapid alignment and to reduce any noise which might be caused by too turbulent an air-stream over the arc. The capillary and support-wire structure is remounted in a new socket shown in Fig. 1. An unmodified *AH-8* arc also is shown for comparison. To remount the arc, the envelope is removed, the support wires then being held in a jig while the glass press is removed. The lead wires are then straightened and inserted in suitable holes in the two connecting rods inserted in the metal-covered linen bakelite socket, these rods also forming the plug for the power leads. The arc and socket are then installed in a new type recorder lamp mounting shown in Fig. 2, which provides three linear and three rotational

degrees of movement, permitting precision alignment of the arc on the recorder. Air is drawn through a glass-wool dust filter at one end of the housing, passes over the arc capillary, and thence through the exit tube to a rubber hose which connects to the exhaust fan mounted on the recorder base. A filter glass in the top of a sheet-metal housing, not shown, permits the operator to inspect the arc while in operation.

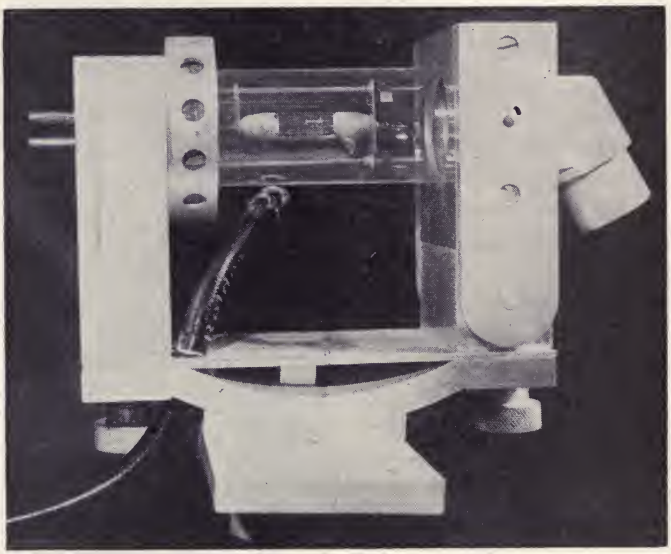

FIG. 2. Arc mounting on film recorder. Contact pins appear at left; air inlet holes and glass-wool filter at left of glass; arc in glass tube; air exit at right; high-tension starting wire enters through bottom.

The general design of the arc rectifier and self-regulating air-suction system was adapted from a Metro-Goldwyn-Mayer design.[4] Fig. 3 is a schematic diagram of the power-supply for the arc. The upper portion of this diagram shows a thyratron rectifying and filtering circuit with output voltage control obtained by phase adjustment of the voltage to the grids. This circuit, while designed for a maximum load current of 3 amperes, is currently being used to provide 0.7 to 1.1 amperes at 140 volts, the excess capacity being available for possible future use of light-filters or other improvements which might require more light.

Without further regulation, the rectifier portion of this circuit permits an 18-per cent change in arc wattage to occur for a 10-per cent change in line voltage. Therefore, the regulating circuit shown in the lower portion of Fig. 3 was developed, which permits only a 3-per cent arc wattage variation for a 10-per cent line voltage fluctuation. The regulator applies a variable d-c grid bias to the thyratrons, controlled by variations in the a-c line voltage. This varying d-c voltage for the grids is obtained from the drop across a resistor in series with a *VR-150-30* tube which is supplied in turn with rectified 180 volts from the a-c source. With a ±10-per cent line-voltage variation, the drop across this resistor will vary between

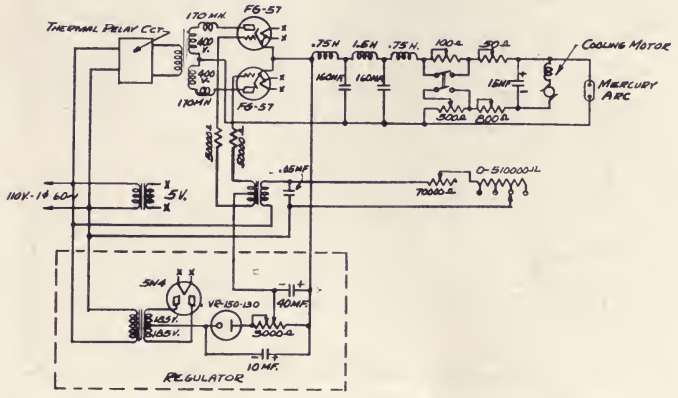

FIG. 3. Mercury arc power supply and air-cooling system.

12 and 48 volts and approximately $^1/_{10}$ of this voltage is applied to the grid circuit in the proper polarity, to compensate for the line variations.

The arcs are started each time they are to be used by externally exciting them with a high-frequency spark which is brought near the glass envelope by the high-tension cable shown in Fig. 2. Between takes the lamps are kept burning on a "hold" position, which keeps them hot at a reduced wattage. One hundred to 160 watts are needed to obtain the unbiased density of 0.65 currently used for the dubbed negative. The power-supply system maintains the desired wattage within ±3 watts, providing a very stable value of negative density.

With conventional types of sound-negative materials formerly employed it was necessary to introduce into the developer a certain quantity of bromide for a given density variation per quantity of film developed. After the transition had been made to the fine-grain stock it was found that this bromide concentration could be dropped to about one-third the former value for an equivalent density variation this reduction being made possible because the bromide released during development by the fine-grain stock is very much less than the amount released by the conventional negative materials. This reduction in bromide concentration is therefore responsible for a considerable gain in negative density for a given gamma and exposure.

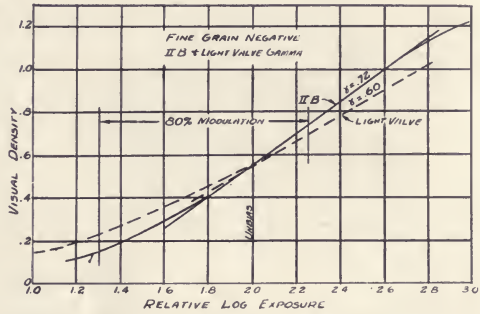

FIG. 4. II*b* and light-valve gamma characteristic of the fine-grain negative.

II*b* and light-valve gamma characteristics for the fine-grain negative stock are shown in Fig. 4. The II*b* characteristic is exposed with tungsten light and the light-valve characteristic is typical of either tungsten or mercury arc exposure. A II*b* gamma of 0.72 and a light-valve gamma of 0.60 are shown for tungsten original recording with an unbiased negative density of 0.55, the negative gamma, however, being adjusted as needed for various emulsions. While the II*b* gamma is higher than the light-valve gamma for this emulsion, it is a satisfactory index for laboratory control with a given developer, this observation being borne out by routine intermodulation tests.

The projected printed-through characteristics of these negative characteristics to the fine-grain positive are shown in Fig. 5. The prints were made with an air-cooled *AH-8* mercury arc using a 2-mm Corning *584* ultraviolet filter.

In Fig. 6 is shown the projected print transmission *vs.* light-valve spacing obtained from a replot of the data shown in Fig. 5. This

static characteristic is essentially a straight line, which sensitometrically confirms the low distortions measured dynamically with either single-frequency or intermodulation recordings.

In Fig. 7 is shown a typical 60/400-cycle intermodulation distortion characteristic for this fine-grain film combination as a function of print density for typical original tungsten recording conditions of negative exposure and development. The minimum distortions shown are lower than those obtained with the conventional types of positive materials which were formerly employed, an observation which is confirmed by aural checks. The numerical magnitude of

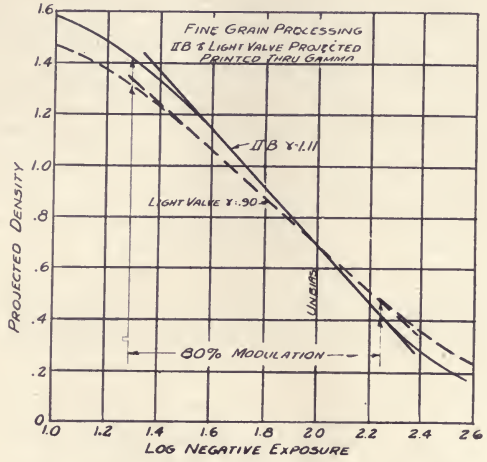

FIG. 5. Projected print density *vs.* log negative exposure for II*b* and light-valve gammas.

the minimum distortion as measured is a function to some degree of the particular type of distortion existing on the film and to the type of analyzer circuit used in making the measurements.

As was expected, the change from low-gamma negative and white-light prints to high-gamma negative with ultraviolet prints has aided in increasing the latitude of print density which can be used with an acceptable rise in distortion. This increased latitude is a distinct advantage, particularly for balancing prints to equal volume and for "print up" to obtain high-volume outputs for special sequences. It is also important to note that the film distortion as heard appears to be less critical to variations of negative density and negative gamma than was the case for the normal positive types of emulsions,

this observation being partially explained by the lower minimum distortions and the broader tolerance curves.

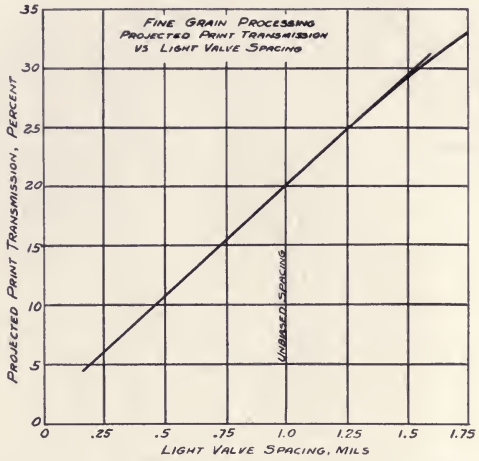

FIG. 6. Projected print transmission *vs.* light-valve spacing.

In conclusion, it can be stated that all the primary objectives of the fine-grain program have been accomplished and placed in operation.

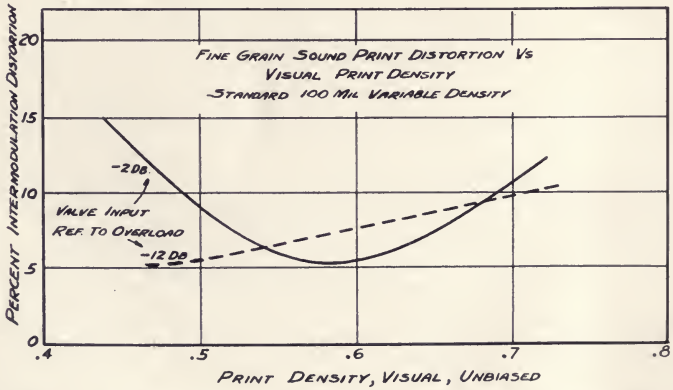

FIG. 7. Intermodulation distortion *vs.* visual unbiased print density.

As still finer grained films and further improvements in recorder optical speed are worked out, greater signal-to-noise ratios may be

expected which will in turn allow us to obtain a still more faithful reproduction of the original sound-source.

This program has been worked out with close coöperation between the film manufacturers, the film laboratory, and the sound department. The writers wish particularly to acknowledge the assistance given by Messrs. Wilkinson, Eich, and Gephart of the laboratory staff.

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LABORATORY MODIFICATION AND PROCEDURE IN CONNECTION WITH FINE-GRAIN RELEASE PRINTING *

JAMES R. WILKINSON AND FERDINAND L. EICH**

Summary.—*While fine-grain emulsions have been in general use for specialty purposes for three years or more, their use as a medium for release prints is comparatively recent. This paper discusses the necessary modifications required in a release laboratory to produce satisfactory fine-grain release prints. The discussion covers light-source, power supply, light testing, and printing equipment. Observations noted while processing the first thirty million feet of release prints are made relative to the behavior and characteristics of the film.*

While a paper on fine-grain film might, at this time, seem somewhat dated, in view of the widespread use of this type of emulsion over the past three years, if the situation is examined closely it is found that fine-grain emulsions, prior to March of the current year, were used largely for sound recording and specialty purposes wherein the improved grain structure has had a beneficial effect upon film noise, frequency response, duplicate negatives, master positives, *etc.* However, during the past six months, this great benefit has been extended substantially into the release print field.

The use of Eastman fine-grain positive, type *1302*, for release prints was of necessity preceded by an extensive program of research and testing. These were joint efforts of laboratory and sound engineers as well as the raw-stock manufacturers, and literally hundreds of tests were made using every possible combination of sensitometric, processing, exposure, and emulsion variation. From this mass of analytical detail were evolved both the final characteristics of the release positive material and the optimal specifications for exposing and processing the same.

One of the early determinations in the above program of testing, and one which later proved to be a safe anchorage in all calculations,

* Presented at the 1941 Fall Meeting at New York, N. Y.; received September 30, 1941.

** Paramount Pictures, Inc., Hollywood, Calif.

was the establishment of a II*b* gamma of 2.50 ± 0.10 as an optimal area of contrast for the visual observation of prints on the screen. All subsequent determinations relative to obtaining optimal sound prints, that is, satisfactory frequency response, minimum distortion, proper density, gamma, noise level, *etc.*, were subject to reconciliation with this predetermined and fixed end point.

To obtain satisfactory print quality from a variable-density sound negative under the above conditions, specifications have been established as indicated in Table I.

TABLE I

Negative control gamma II*b*	0.67
Negative density	0.65
Print control gamma II*b*	2.50
Print density	0.58
Intermodulation distortion	5%

The above has been covered in detail by C. R. Daily and I. M. Chambers.[1]

The first requirement for satisfactory use of fine-grain film was the need for sufficient light to print the material. The original experiment in printing fine-grain emulsions employed the use of mercury-vapor high-pressure lamps. These had proved suitable for fine-grain master positive printing and had high efficiency in the ultraviolet spectrum for sound printing. The levels of light-intensity encountered in the use of fine-grain emulsions developed in the Paramount print developer are shown in Fig. 1. This diagram includes the present fine-grain release emulsion in use at the present time.

In order to maintain as flexible a printing system as possible a ceiling level of light-intensity was adopted which would provide ample exposure for master positive emulsions. To secure this, the production printers were equipped with a condenser lens to concentrate the light at the back aperture of the Bell & Howell Model *D* printer. To insure a uniform illumination and printing point increment a ground-glass was placed between the back aperture and the lens. The light-source, which is an *AH-8* mercury-vapor lamp, is positioned to throw a circular spot of light on the ground-glass. To provide easy adjustment to different light-intensity levels for accommodating the various emulsion types, light attenuators are inserted between the lens and back aperture. These attenuators are calibrated so that a level of intensity can be obtained whenever de-

sired without changing the wattage setting of the lamp. Fig. 2 is a diagram of the printing set-up. The mercury-vapor lamp is operated from a 400-volt, d-c generator, which has a vacuum-tube regulator for maintaining the supply voltage at ±0.1 volt. The wattage of the lamps is adjusted by means of a rheostat in the individual lamp circuit to give a standard level of intensity. This brings the wattage

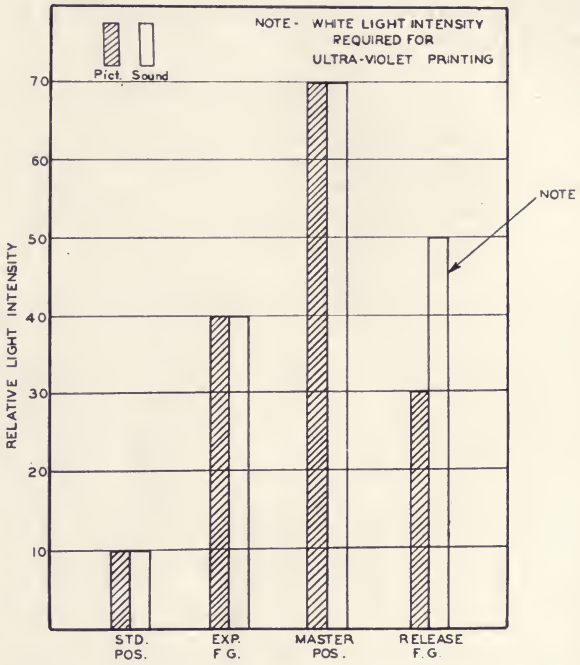

FIG. 1. White light-intensity levels for various printing emulsions.

range of the lamps between 60 and 80 watts. Fig. 3 is the circuit used on the production printer lamps. It will be noted that 320 microfarads of capacitance are placed across the generator output to smooth out the voltage ripple. For printing the sound a Corning No. *584* filter, 2 mm thick, is inserted between the lens and back shutter, and for picture the filter is replaced with a ground-glass.

In timing the printer exposure, the sound negative density is measured on the densitometer and the printer point selected from a calibration chart. For picture timing, however, the Cinex tester is

retained. This tester is equipped with an *AH-8* mercury lamp, mounted in a horizontal position in the base of the tester, and provides adequate exposure for testing on master positive emulsions. In order to drop the intensity level for testing on fine-grain release positive, a wire mesh screen is placed between the exposure plane and the lamp. The printer-point increment on both the Cinex and the printers is maintained at a density of 0.06 per printer point.

In modifying the Bell & Howell Model *119A* automatic release printers a more involved change was required to obtain suitable exposure. The distance between the light-source and exposure plane is much greater and the light-beam must pass through a very narrow

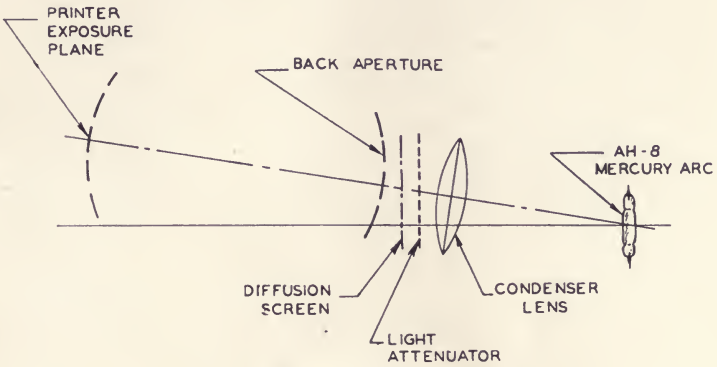

FIG. 2. Production printer light-source.

aperture before reaching the exposure plane. Due to the fact that a film with a variable-width density is used to control the printer light at the narrow aperture, called the mat aperture, the mercury lamp is very desirable due to the coolness of the light when concentrated at this aperture. The optical system of the printer was altered as shown in Fig. 4, to increase the efficiency of the system. This shows a side view of the light system. A 25-degree prism is inserted in horizontal axis *A-A* with the base of the prism facing the 90-degree prism. Normally with the 90-degree prism in the vertical position, the light passing through it would be reflected upward in a vertical direction. However, since the exposure aperture is offset from the true vertical axis of the 90-degree prism by 25 degrees, as viewed from the front of the printer through the plane *B-B*, the vertical beam of light would normally not reach this exposure aperture. In order to

keep all the elements in line on the *A-A* axis and obtain an offset in the beam at the exposure aperture, the 25-degree prism is inserted in the optical system and for convenience is placed as indicated in Fig. 4. This then rotates the normal vertical axis *B-B* on the axis *A-A* as a pivot by 25 degrees, and produces a light-image at the exposure aperture. Since the Model *119-A* printers have a lower light efficiency than the Model *D* printers, due to the type of optical system required, the *AH-8* lamp was modified to permit higher range of wattage. This was obtained by air-cooling the lamp by means of a

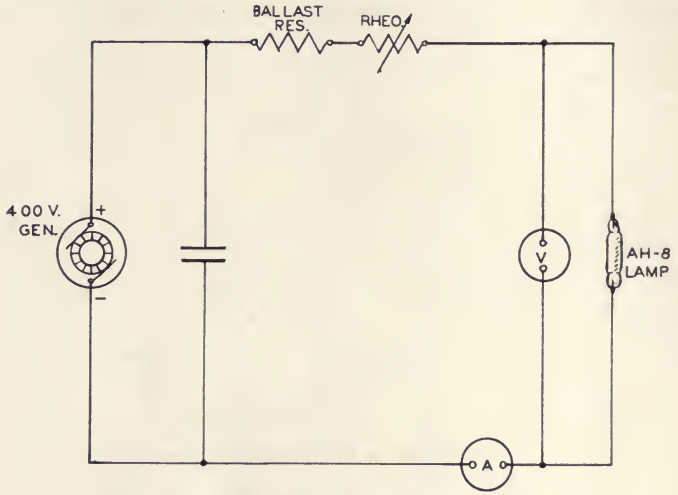

FIG. 3. Lamp circuit for production printers.

blower whose motor is connected across the lamp terminals. This cooling system tends to stabilize the lamp and hold it at a constant potential.

An additional piece of optics is necessary in the sound-track side as compared to the picture side, since the sound is printed with a Corning No. *584* filter, the same as the production sound. In order to compensate for the additional loss of light due to the filter, a quartz integrating bar is positioned between the mat aperture and the exposure plane, to collect all the light and concentrate it at the sound-printing aperture.

By using forced cooling on the lamps the range of wattage under which the lamp operates is from 50 to 150 watts. The lamp is main-

tained at a voltage of 90 to 100 volts by means of the blower speed, and the current in the lamp is adjusted with the lamp rheostat. Fig. 5 shows the circuit for the release printer lamps. The blower is operated with a 220-volt d-c motor connected across the lamp, and as the voltage across the lamp varies, the blower speed changes to correct the voltage change. With the lamp operating at 100 volts, a 300-volt d-c. generator is used which provides ample ballast voltage for the lamp. An electrical filter is provided in each lamp circuit to

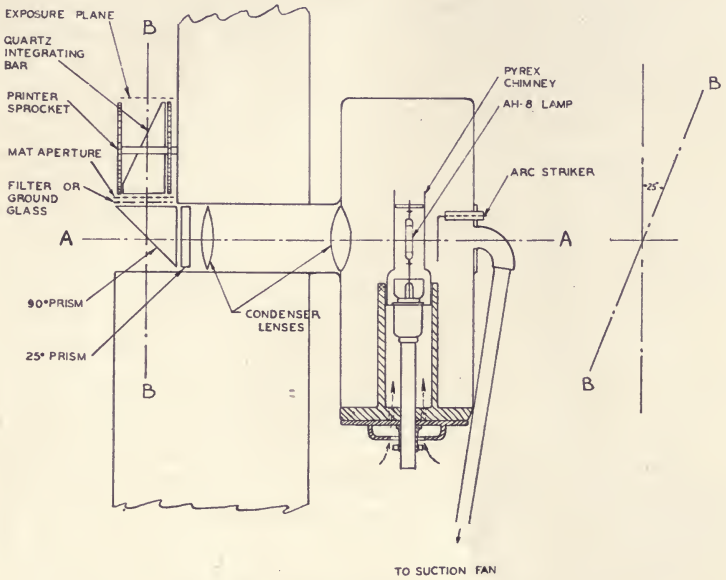

FIG. 4. Release printer light system.

eliminate the voltage ripple from the generator. This is necessary because the mercury lamp is stroboscopic in nature and will follow slight changes in voltage.

Fig. 6 shows the lamp assembly for the release printer. The glass envelope of the lamp is removed and replaced with a Pyrex chimney, which is held in place by the base as shown in the photograph. Fig. 7 shows the position of the suction fan in relation to the lamp house.

For starting the lamps a small insulated wire has been located directly behind the lamp. A high-voltage spark coil, touched to the wire, induces a voltage in the lamp which ionizes the gas and strikes

the arc. This method permits striking the arc without the need of opening the lamp house.

Certain of the major studios divide release printing between West Coast and East Coast plants. Due to existing national conditions, it has become increasingly difficult for laboratories contemplating modification to procure the necessary materials—electrical, mechanical, and optical, to complete their program rapidly. This situation has caused some unavoidable delays in obtaining the full benefit of the complete fine-grain program. For this interval and until the various laboratories have completed their necessary modifications, a method has been established, and is in actual practice, whereby

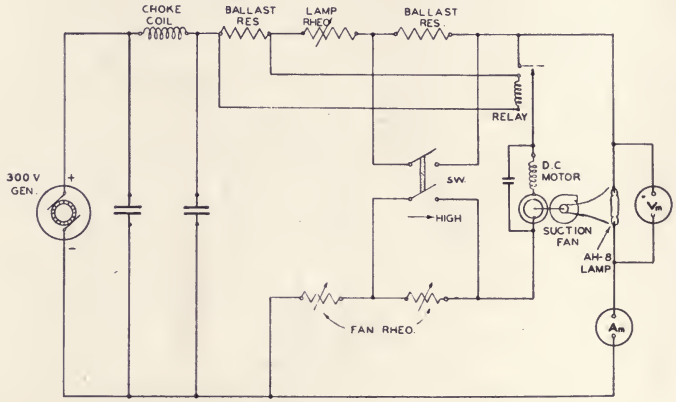

FIG. 5. Lamp circuit for release printers.

virtually all the improvement embodied in the first three steps of sound reproduction with fine-grain film, that is, original recording, dubbing prints, and final release sound negative, may be retained even though the final release prints are made on conventional positives.

This method comprises the preparation of a photographic duplicate sound negative which permits printing by white light to the conventional positives. From the final release negative a fine-grain master positive is prepared. Printing is with ultraviolet light and the master is developed to a gamma of 1.45. From this fine-grain master the duplicate negative is printed using another fine-grain material of the proper characteristics. Printer exposure is unfiltered mercury light and the negative is developed to a density of 0.60 and a gamma of 0.65.

This fine-grain duplicate negative may then be printed with normal white-light exposure to the conventional positives with an overall loss of only 1.5 db at 7000 cycles and with a quality of reproduction that is very slightly inferior due to the final release print medium. Fig. 8 shows the comparison between distortions of the dupe *versus* the original prints.

This procedure sacrifices completely the great benefits of fine-grain quality to the picture, but it does retain the major portion of the improvement which has been engineered by the sound division.

FIG. 6. Lamp assembly for release printer.

Prior to the use of fine-grain positive for release purposes, there had been no practical study, nor was knowledge available, relative to the effect upon developing solutions of large and continuous footages of this type of emulsion. It was with considerable apprehension and many anxious moments that the first few days of three to four hundred thousand feet per day were carefully checked. However, visions of developer imbalance and weird replenishment requirements due to obscure and unanticipated chemical reactions proved to be quite groundless. Slight changes were noted but they were moderate in proportion and orderly in their progression, and were easily adjusted to permit the maintenance of print specifications which had been carefully established.

Previous development of moderate footages had indicated no change would be required in the developing formula. This has likewise proved to be correct with heavy footage and, beyond a slightly higher ratio of hydroquinone plus a moderate increase in the *p*H value to maintain the correct gamma, the formula has remained unaltered. The emulsion does not carry off the same quantity of developing solution as did former positives, consequently less actual replenisher

is required to maintain the solutions. The emulsion, being somewhat thinner than former positive emulsions, dries with considerably less heat in the drybox, and due to this characteristic is ejected in a ribbon-like flat condition with no inclination to curl. Some difficulty has been encountered in processing the emulsion following develop-

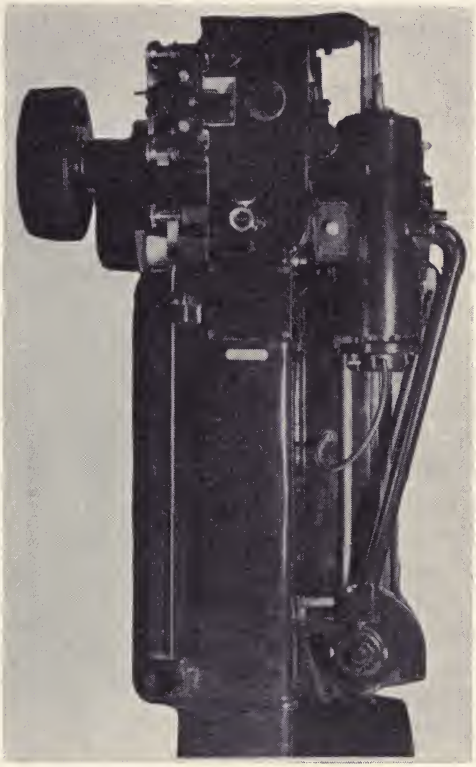

FIG. 7. Showing position of suction fan in relation to lamp house.

ment, and adjustments were necessary in both the processing solution and in the method of application to insure a well lubricated surface. The emulsion has much less pull to its surface than former emulsions, and due to its extreme smoothness the surface was, at first, non-absorbing and retained an insufficient amount of the processing fluid.

As to uniformity, the stock is equal if not actually superior to the former positive. Roll to roll tests on an emulsion of two million feet show extremely slight variation and there has been practically no drifting tendency either in gamma or density.

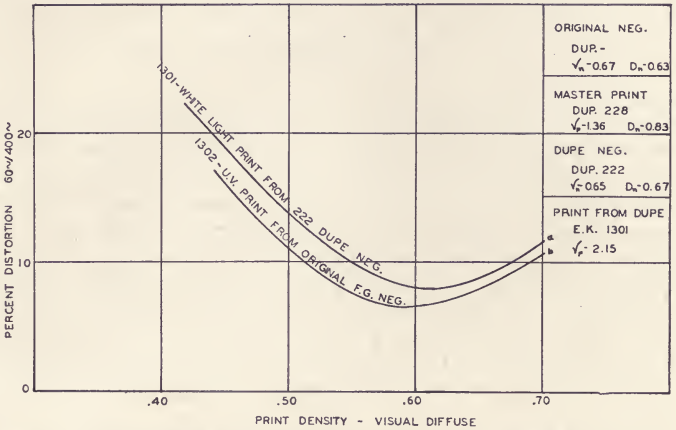

FIG. 8. Intermodulation distortion curves for (*a*) print from dupe negative, and (*b*) print from original negative.

Viewing the entire fine-grain program in retrospect, a tremendous amount of effort and expense has been necessary to bring it to its successful conclusion. As in every worthwhile undertaking problems were encountered and their solution was, at times, difficult. Nevertheless, these problems have all been well within the bounds of reason and the improvement which has been achieved in sound and picture quality is ample reward for the efforts expended.

REFERENCE

[1] DAILY, C. R., AND CHAMBERS, I. M.: "Production and Release Applications of Fine-Grain Films for Variable-Density Sound Recording," *J. Soc. Mot. Pict. Eng.*, **XXXVIII** (Jan., 1942), p. 45.

DISCUSSION

DR. FRAYNE: The improvement in the appearance of the fine-grain release prints appears to have been accompanied by no increase in noise from the sound-track. This would seem to indicate that there had been no increase in grain size in the more recent fine-grain emulsions offered to the motion picture industry. It is my understanding that at least one of the film companies has succeeded in removing the brownish color of the image by the addition of a blackening agent which results in improved picture quality and does not in any way interfere with the sound quality obtained from these types of emulsions.

A NOTE ON THE PROCESSING OF EASTMAN 1302 FINE GRAIN RELEASE POSITIVE IN HOLLYWOOD*

V. C. SHANER**

Summary.—*A brief historical résumé is given of a series of fine-grain films that have been put upon the market during the past four years. This series of fine-grain films culminated with the acceptance of Eastman 1302 fine-grain release positive at one Hollywood laboratory to the exclusion of regular positive of the 1301 type for release printing. Experimental data are presented to show the comparative sensitometric characteristics of fine-grain positive 1302 and regular positive 1301 at various pH values and potassium bromide concentrations typical of Hollywood positive developers. A basic positive developer formula derived from chemical analyses of every release positive developer in Hollywood was used in the experimental work. Some practical facts are discussed, based upon the experiences obtained from the initial use of the fine-grain film in Hollywood.*

The introduction during the year 1941 of Eastman Fine Grain Release Positive, Type *1302*, marked the completion of a series of fine-grain films which have been made available to the motion picture industry during the past several years. Before discussing this new film and its processing in detail, it may be well to review briefly the preceding fine-grain products.

In 1937, two fine-grain duplicating materials[1] were introduced to meet the need of eliminating excessive graininess in prints made from duplicate negatives. These two films, Eastman Fine Grain Duplicating Positive, Type *1365*, and Eastman Fine Grain Panchromatic Duplicating Negative, Type *1203*, won ready acceptance and today are standard products in the duplicating field. The year 1938 marked the appearance of Eastman Fine Grain Sound Recording Film, Type *1360*, the first of several emulsion types to bear this name. Designed for use in variable-area recording, it gave improved high-frequency response together with a definite decrease in ground-noise. The picture-negative films had their major improvement from the standpoint of fine-grain characteristics in 1938 also, and in that year

* Presented at the 1941 Fall Meeting at New York, N. Y.; received October 10, 1941.

** Eastman Kodak Co., Hollywood, Calif.

Eastman Plus-*X*, Type *1231*, was first manufactured and submitted to the trade.[2] This film has twice the speed of Eastman Super-*X*, Type *1227*, its predecessor as standard production negative film, yet is definitely finer in grain. In 1939, another Fine Grain Sound Recording Film, Type *1366*, brought to the field of variable-density recording the improved sound quality and reduced ground-noise which the *1360* type had made possible in variable-area recording. It is interesting to note here that research on fine-grain sound-recording materials has not ceased, and even today new experimental films are continually being developed and tried out in production.

The present year, 1941, has witnessed the introduction of Eastman Fine Grain Release Positive, Type *1302*, and its adoption to the exclusion of the regular Positive, Type *1301*, in the production work of one major Hollywood release laboratory, namely, Paramount. Other laboratories in this area have also made some production use of the *1302* type. It is in this new fine-grain release print material that the complete effects of the other fine-grain materials are realized and extended to the theater audience.

In the period of months since the use of the Fine Grain Release Positive began in Hollywood, approximately 50,000,000 feet have been consumed in release print manufacture. The result, a finer grained image on the theater screen, has been attained not only through the contribution of the film manufacturer in developing a better product, but also through the ability of the motion picture laboratory technicians to work out the problems involved in the use of the new film.

The manufacture of a film with finer-grain characteristics necessitated a sacrifice of emulsion speed, with the result that the Fine Grain Release Positive has approximately one-quarter the emulsion speed of the regular *1301* Positive. Laboratory technicians were, therefore, confronted with the major problem of readjusting the exposure level of production printers. Some laboratories solved this problem satisfactorily by equipping the printers with mercury-vapor lamps, which emit more radiation than tungsten lamps in the shorter wavelengths, to which the film is most sensitive. Other laboratories installed high-intensity tungsten lamps and, in some instances, used reflectors to increase the effective exposure. Thus the Hollywood laboratories have modified their printing equipment in one way or another to accommodate the lower-speed film.

There is another characteristic of the Fine Grain Release Positive

which requires consideration, although it did not necessitate so great an alteration in production laboratory technic as did the lower emulsion speed. If two prints from the same negative, one on regular Positive, Type *1301*, and the other on Fine Grain Release Positive, Type *1302*, are matched for density and contrast when viewed by diffused light over an illuminator, then these same prints, when projected, will no longer match in quality. The *1302* print will be lighter in density than the *1301* print, and will have lower contrast. These effects are due to differences in the optical characteristics of the silver particles in the two films.

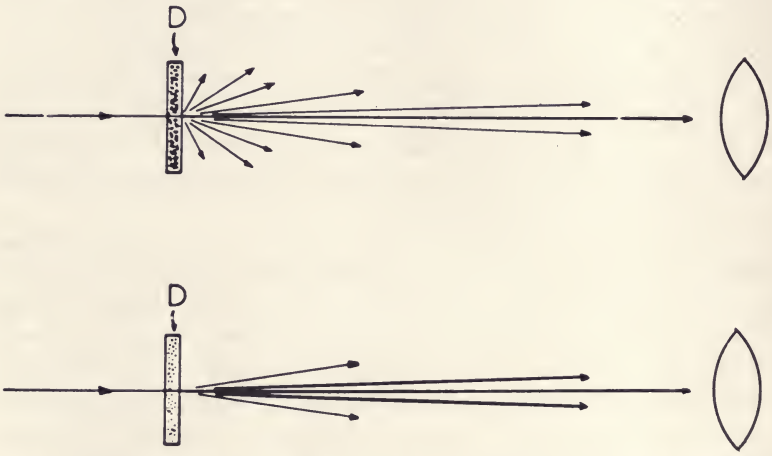

FIG. 1. Distribution of light flux through the two film types used in projection.

In Fig. 1, polar diagrams illustrate the distribution of light flux in the beam of light transmitted through the two film types under conditions similar to those encountered in projection. It is readily apparent that the smaller silver particles of the fine-grain print produce less scattering of the transmitted light. Thus, although the prints appear equal in density and contrast when viewed by diffused light over an illuminator, under the conditions of specular illumination which prevail in a projector, the lens receives more light from the fine-grain print. The result is lighter and less contrasty screen quality.

Experience has shown that in addition to the increase in exposure required by the lower speed of the *1302* emulsion, a further increase of approximately two Bell & Howell printer steps is required to bring

the screen density of a *1302* print up to the screen density of a *1301* print. To compensate for the lower contrast seen on the screen, the *1302* print must also be developed to a higher gamma, approximately 2.50, as contrasted with the normal *1301* gamma of 2.10. With these changes, projected prints on the two materials can be matched for density and contrast. This does not mean, however, that they are equal from the standpoint of general photographic quality. Actually, the *1302* print is of much higher quality because the lower graininess produces a smoother, rounder appearance of the photographic image on the screen.

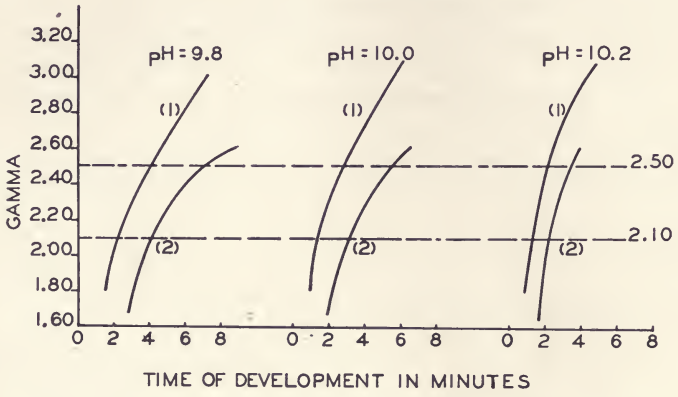

FIG. 2. Time of development *vs.* gamma; *X-2* developer; (*1*) *1302;* (*2*) *1301.*

Generally speaking, fine grained materials have rapid rate-of-development characteristics; that is, the contrast increases rapidly with time of development. Thus the development rate of *1302* is somewhat higher than that of *1301.* In view of the higher contrast requirements of *1302* prints, this is a desirable feature, since in many cases longer times of development would result in decreased production.

The time-gamma curves in Fig. 2 show the comparative rates of development of *1301* and *1302* in a positive developer adjusted to three different *p*H levels. The developer, designated *X-2,* is derived from chemical analyses of all the positive developer solutions in use in Hollywood, using methods previously described.[3] It is employed by the Eastman West Coast Laboratory for many test purposes.

The actual constituents, as well as the amounts of each used to make up the basic formula, are contained in the following tabulation:

Elon	1.5 grams
Hydroquinone	3.0 grams
Sodium Sulfite, desiccated	40.0 grams
Potassium Bromide	2.0 grams
Sodium Carbonate, desiccated	17.0 grams
Water to make	1.0 liter
*p*H	10.0

The curves in Fig. 2 were obtained from data derived from the development of regular Type II*b* sensitometric exposures. Prior to exposure, the film samples were conditioned for two hours in an atmosphere of 68 per cent relative humidity at a dry-bulb temperature of 70°F. The strips were developed at 67°F in a sensitometric developing machine previously described in the JOURNAL.[4]

The *p*H values were measured with a Beckman laboratory model *p*H-meter equipped with an improved glass electrode which has no sodium ion correction in the *p*H range of these tests. Developer modifications having *p*H values of 9.8 and 10.2 were obtained by altering the amount of desiccated sodium carbonate in the *X-2* formula to 7 and 22 grams per liter, respectively.

At a *p*H value of 9.8, a development time of 4.1 minutes was required to obtain a gamma of 2.50 with *1302*. At the same time of development a gamma of 2.10 was obtained with *1301*. Similarly, at *p*H values of 10.0 and 10.2, development times of approximately 3.0 and 2.0 minutes gave the desired gamma values with both films. Since the *p*H values of 9.8 to 10.2 represent the current working range of the positive developers used in Hollywood, it becomes clear that *1302* can be developed at machine speeds approximately the same as those used with *1301*, even though a higher contrast is required.

The chemical analyses of the positive developers used in Hollywood laboratories disclosed potassium bromide concentrations ranging from 0.75 to 4.0 grams per liter. Although the effects of various concentrations of this chemical on positive film of the *1301* type are well known to laboratory chemists, it may be of interest to summarize them here. An increase in potassium bromide concentration produces a corresponding decrease in density. If the bromide concentration is increased to approximately 2 grams per liter, gamma in-

creases, but if the bromide concentration is increased to more than 2 grams per liter, the retarding effect on development is sufficient to decrease the gamma as well as the density obtained at a given time of development.

Fig. 3 shows the effects of various concentrations of potassium bromide on the gamma and density of *1301* and *1302* developed in the *X-2* developer. It will be noted that bromide has similar effects

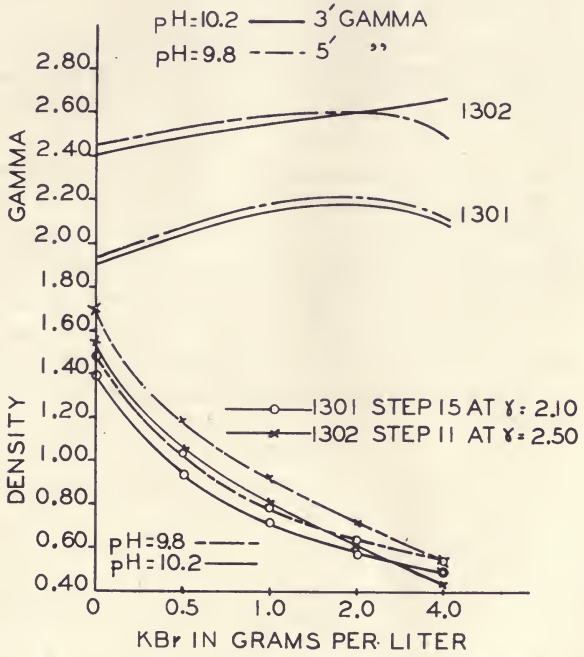

FIG. 3. Effect of bromide on gamma and density.

on the contrast of both films at a *p*H of 9.8. At a *p*H of 10.2, however, the gamma of *1302* increases with increasing bromide concentration up to 4.0 grams per liter. Thus, at higher *p*H levels, the decrease in gamma experienced with *1301* at high bromide concentrations does not appear with *1302*.

Referring now to the density curves, it will be seen that at a bromide concentration of 1.0 gram per liter, the densities obtained with *1302* were 0.93 at a *p*H of 9.8, and 0.80 at a *p*H of 10.2, while at a concentration of 4.0 grams per liter the densities were 0.54 at a *p*H of 9.8 and 0.43 at a *p*H of 10.2. To the practical laboratory chemist, these

decreases in density are equivalent to an exposure loss of about five Bell & Howell printer steps at a gamma of 2.50. Under corresponding conditions, the densities obtained with *1301* were 0.78, 0.70, 0.58, and 0.50, respectively. Here the decreases in density are equivalent to an exposure loss of approximately three Bell & Howell printer steps at a gamma of 2.10. Since the exposure loss is two printer steps less than that experienced with *1302*, it is apparent that the rate of decline of density with increasing bromide concentration is somewhat greater for the fine-grain film.

Objectionable fog values were encountered on both emulsion types in *X-2* developer containing no potassium bromide. However, the fog values obtained in the absence of bromide were lower on *1302* than on *1301*.

These data have been presented to illustrate the characteristics of Eastman Fine Grain Release Positive Film, Type *1302*, under the conditions existing in Hollywood release print laboratories. The use of radically different developer formulas may lead to conclusions at variance with those expressed here, and in some cases it may be necessary to modify such formulas in order to secure the best results. It is felt, however, that the information given here should provide a basis for activities with the new film outside the Hollywood area.

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[2] HUSE, E., AND CHAMBERS, G. A.: "Three New Eastman Negative Emulsions," *Amer. Cinemat.* (Dec., 1938), p. 187.

[3] ATKINSON, R. B., AND SHANER, V. C.: "Chemical Analysis of Photographic Developers and Fixing Baths," *J. Soc. Mot. Pict. Eng.*, **XXXIV** (May, 1940), p. 485.

[4] JONES, L. A., RUSSELL, M. E., AND BEACHAM, H. R.: "Machine for Sensitometric Work," *J. Soc. Mot. Pict. Eng.*, **XXVIII** (Jan., 1937), p. 73.

DISCUSSION

MR. GASKI: How did you arrive at the *X-2* formula for *1302?*

MR. HUSE: For some period of time a number of samples of actual machine positive developers were taken from each of the various laboratories in Hollywood. Chemical analyses of these various developer samples were made. Following this, an average formula was derived from these analytical data, which formula in a sense represented the numerical average of all.

Numerous photographic tests later proved that this formula gave us a good working developer for correctly analyzing the behavior of films in terms of laboratory practice.

MR. HYNDMAN: The majority of laboratories in New York City and the surrounding area have made printing and developing tests on fine-grain release positive films. Consolidated and DeLuxe Laboratories have printed complete releases on this material. Within thirty days other laboratories will be ready to do release printing on this film and probably within the next thirty to ninety days several laboratories will do all their release printing on this film.

Most of the eastern laboratories have found it necessary to revamp their printers so as to obtain sufficient exposure to print this film. A number of laboratories have also made changes in their positive developer bath to secure what was considered the best photographic quality.

MR. GRIFFITH: Why, in the processing of fine-grain film, is less developer carried out of the developer tank by the film itself?

MR. HUSE: The physical characteristics of *1302* are such that less developer is actually absorbed per unit length or unit area of the film during processing.

REPORT OF THE THEATER ENGINEERING COMMITTEE*

Summary.—*This is an account of the work of the several sub-committees of the Theater Engineering Committee during the past two years. The report of the Sub-Committee on Projection Practice embodies a preliminary study of safety factors in projection rooms, specifically with reference to the use of hand-operated fire extinguishers.*

The report of the Sub-Committee on Theater Design includes a preliminary study of the basic shapes of theaters and advantageous seating zones, including a report on a study of these factors made in the Surrey Theater in New York.

A report of the Sub-Committee on Screen Brightness deals with proposed specifications for meters for measuring incident and reflected screen light in theaters, and the efforts of the Committee to encourage the manufacture of such instruments for the industry.

In a previous report of the Committee, published in the December, 1940, issue of the JOURNAL, announcement of the reorganization of the Theater Engineering Committee was first made. Originally, the Committee consisted of the two Sub-Committees on Projection Practice and Theater Design. Under the new arrangement, a third sub-committee took over the work dealing with screen brightness, leaving the Projection Practice Sub-Committee to concentrate its attention on projection problems proper.

The personnel of the Theater Engineering Committee, divided into the three sub-committees, is as follows:

THEATER ENGINEERING COMMITTEE

ALFRED N. GOLDSMITH, *Chairman*

Projection Practice Sub-Committee

H. RUBIN, *Chairman*

H. ANDERSON	E. R. GEJB	P. J. LARSEN
T. C. BARROWS	M. GESSIN	J. H. LITTENBERG
H. D. BEHR	A. GOODMAN	E. R. MORIN
K. BRENKERT	H. GRIFFIN	J. R. PRATER
F. E. CAHILL, JR.	S. HARRIS	F. H. RICHARDSON
C. C. DASH	J. J. HOPKINS	J. J. SEFING

* Presented at the 1941 Fall Meeting at New York, N. Y.; received October, 15, 1941.

A. S. DICKINSON
J. K. ELDERKIN
J. FRANK, JR.
R. R. FRENCH
C. HORSTMAN
L. B. ISAAC
I. JACOBSEN
R. O. WALKER
V. A. WELMAN
H. E. WHITE
A. T. WILLIAMS

Theater Design Sub-Committee

B. SCHLANGER, *Chairman*

F. W. ALEXA
D. EBERSON
J. FRANK, JR.
M. M. HARE
S. HARRIS
C. HORSTMAN
E. R. MORIN
K. C. MORRICAL
I. L. NIXON
C. C. POTWIN
A. L. RAVEN
R. F. ROSS
E. S. SEELEY
J. J. SEFING

Screen Brightness Sub-Committee

F. E. CARLSON, *Chairman*

F. T. BOWDITCH
W. F. LITTLE
S. HARRIS
W. B. RAYTON
C. TUTTLE
H. E. WHITE
A. T. WILLIAMS

Sub-Committee on Projection Practice

Working Committee on Fire Hazards.—A special subject before the Working Committee on Fire Hazards dealt with the question of including hand-operated fire extinguishers as part of the equipment of the motion picture projection room. The first step in the study was to send communications to various manufacturers of hand-operated fire extinguishers, stating the problem facing the Committee and asking specifically the following questions:

(*1*) What effect has your extinguisher on burning film, especially of the cellulose nitrate type?

(*2*) What damage to other equipment in the projection room might be incurred from the use of the extinguisher?

(*3*) What, if any, possibly toxic vapors are produced from the use of the extinguisher on burning cellulose nitrate film, and in what amounts?

In view of the inadequacy of information pertaining to these subjects, no definite answers to these questions were available either from the manufacturers of the equipment or from the information at the command of the Committee. However, the questions indicate some of the important data that should be obtained by the Committee aside from the question of establishing a policy with regard to the use of hand-operated extinguishers in projection rooms.

A reply received from Mr. R. M. O'Connell, Service Engineer of Underwriters Laboratories, Inc., Chicago, contains paragraphs of special interest to the Committee, since the thoughts expressed agree

strongly with the feelings of the Projection Practice Committee expressed frequently in previous reports and at many meetings of the Committee. These paragraphs follow:

We also attach a copy of the *Regulations of the NBFU for Nitrocellulose Motion Picture Film.* Section 19 of this pamphlet is intended to afford necessary safeguards for booths, including vents, shutters, and noncombustible construction. We may call your attention to the note following sub-paragraph J appearing on p. 22 of this pamphlet. This note recommends the installation of automatic sprinklers wherever practicable.

In our study of the subject we have come to believe that the fundamental purpose of the above Regulations is to afford protection to the other parts of the building and to the occupants rather than to suggest means of controlling any film fires which may actually occur within the projection room. As you know, such fires burn rapidly, give off intense heat, and great volumes of suffocating fumes and in our opinion ordinarily could not be controlled by hand-operated extinguishers of the usual type, even though it were possible for the occupants of the projection room to put such extinguishers into action and remain within the booth for any appreciable time following the start of a fire. As you know, nitrocellulose film is not dependent upon supplies of oxygen from the surrounding atmosphere. The entire intent of the Regulations therefore seems to be that the operator should try to get out of the room or booth as quickly as possible and hope that the booth itself was so constructed and ventilated that the film fire would burn out without extending into the building and without emitting a hazardous volume of fumes to the rest of the surroundings.

In our opinion the safety of booths can not be made dependent upon hand fire extinguishers. It would, of course, be well to have proper extinguishers close at hand outside of the booth in case a need for them should arise. You will observe in Section 14, Rule 144, of the National Board Regulations, a note which recommends small hose equipment and extinguishers except in film vaults. This is probably a reasonable recommendation, but we would not depend too much on extinguishers to handle film fires unless of the very smallest size and only if the extinguishers were brought into action quickly before very much film was involved. It is probably more true of films than of other combustibles that protection is to be sought in preventing fires rather than by provision for extinguishing them after they have once started.

The Chairman has obtained permission of Mr. O'Connell to quote these paragraphs in a report of the Committee.

Another question considered by the Committee was a possible inconsistency between Sections 144 and 218 of the *Regulations of the National Board of Fire Underwriters for Nitrocellulose Motion Picture Film* as recommended by the National Fire Protection Association and published by the National Board of Fire Underwriters as NBFU pamphlet No. 40.

Section 144 reads as follows:

Every room in which film is stored or handled, except film vaults, shall be provided with first aid fire appliances of types using water or water solutions. (Then follows a list of several extinguishers considered suitable.)

Section 218 reads as follows:

In the event of film fire in a projector or elsewhere in a projection or rewind room, the projectionist should immediately shut down the projection machine and arc lamps, operate the shutter release at the nearest point to him, turn on the auditorium lights, leave the projection room, and notify the manager of the theater or building.

It was pointed out that if the projectionist should leave the projection room in the event of a fire, there would be no point in having hand-operated extinguishers inside the projection room.

The Committee felt that a hand extinguisher might perhaps be of use in cases of small fires from sources other than film, but in turn it was pointed out that nothing that would be likely to burn was permitted in the projection rooms, according to the *Regulations*.

There is apparently no definite information concerning cases of fire where hand extinguishers have been used, and most of the information available with regard to film fires in the projection room and the extinction of such fires is incomplete and sometimes questionable.

The general consensus of the Committee may be summed up as follows:

(*1*) The Committee felt that no hand-operated extinguishers should be in the projection room.

(*2*) One or more hand extinguishers should be available immediately outside the door or doors of the projection room.

(*3*) The Committee still feels that in the event of film fire, the projectionist should immediately leave the projection room, so that Section 218 of the *Regulations* is to be regarded as satisfactory, but that Section 144 should either be omitted entirely or revised in accordance with Items 1 and 2.

Working Committee on Tools and Tolerances.—It is the conviction of the Projection Practice Sub-Committee that progress in the projection art requires that there be promptly made available, preferably by the projector manufacturers, information on exact methods and appropriate tools for measuring the wear of projector parts, data on the permissible maximum tolerable amount of wear of each part before required replacement, accurate methods of measuring such op-

erating values as film tension at the gate, and the corresponding convenient tools for measuring and adjusting such operating conditions.

The Sub-Committee points out that it has endeavored for a period of years to secure such information and tools, and at this time regards the lack of such material as detrimental to the advancement of projection and accordingly urges the early availability of such data and tools.

Sub-Committee on Theater Design

The Theater Design Sub-Committee is endeavoring to formulate plans for a series of surveys from which information may be derived which will indicate those zones of seating in the motion picture auditorium most preferred for comfortable viewing of the pictures. It is intended also to locate the zones of second, third, and even lesser choice for seating as selected by the audience after the more highly preferred areas are filled.

The Committee fully realized that there would be many significant factors which might change the pattern of the preferred zones; for example, the size and brightness of the picture might have a direct influence on the pattern. Also, the traffic lines into the auditorium and the placing of the aisle leading to the seats would be relevant factors. While it is realized that poor sightlines due to improperly pitched floors and uncomfortable chairs might influence the location of preferred seating zones, the Committee feels that it would be wise to place little stress on these last two factors because theaters having such conditions could and probably should be avoided for this survey work.

To arrive at any worthwhile conclusions, it is felt that it would be necessary to make surveys for auditoriums of varied basic shapes, such as the square shape, the extremely elongated rectangle, and in-between shapes. It would also be necessary to survey theaters of varied capacities, the 600, 900, 1200-seat capacities being recommended for the tests. It would be preferable if the size and brightness of the picture could be varied for a given seating pattern so that their influence could be more definitely observed.

The first survey was made in a theater under actual operating conditions. This type of survey can be made fairly accurate and gives a true picture of the preferred seating zones. The main difficulty, however, arises from the fact that it is necessary to have at

least one checker for approximately every 60 chairs in an auditorium. Each checker must have a chart in front of him indicating the chairs in his zone so that he can mark the chairs as they become occupied.

Still another method of checking the preferred seating zones was considered in which the audience would be brought to an auditorium chosen for test purposes, and, under different conditions be asked to seat themselves in accordance with their ideas of comfortable viewing positions. It is probably true that an unsuspecting audience would give more conclusive information but there are definite advantages in this latter type of survey. It would not be necessary to have large squads of checkers. It must be remembered that considerable travel and arranging of available time is involved in getting together a group of checkers to make a survey in theaters in actual operation. In the plan which involves the use of an audience chosen for the test purpose, the necessary changes in picture size and brightness could be made and their effect noted on the specific audience. It would also be possible to rope off designated seating areas in which the basic shape of the seating pattern could be varied to check on the influence of the basic shape. Of course, one major obstacle to this type of survey would be the difficulty of obtaining an auditorium equipped with the necessary chairs and projection equipment for the tests. The difficulty of obtaining a sufficiently large audience could be minimized by spacing the chairs farther apart in both directions than would be normal practice so to decrease the required number of viewers; for example, the normal audience of 600 could be tested with approximately 200 persons.

The Committee made an actual survey in the Surrey Theater in New York City. The theater was open for business and the tests were made starting at 6:45 P. M. and ending at 9 P. M. The theater has a capacity of 570 chairs, and in the hours indicated 453 people entered the theater to view the screen performances. The accompanying diagram indicates the plan of the theater, the position of the screen, and the like. The results of this survey are herewith given and the sub-committee may continue with a series of these surveys unless it is found that other more practicable methods can be used to arrive at the necessary results.

The survey shown in Fig. 1 was taken, as stated, at the Surrey Theater located in the Bronx, New York. Eleven members of the Sub-Committee entered the theater on a week-day evening at about 6:30 P. M. Each sub-committee man occupied a specified seat from which he could view an area of approximately 50 seats. The survey

started at 6:45 P. M. and terminated at 9 P. M., the evening period in which the major part of the audience was expected to arrive. The total period was divided into three periods: 6:45 P. M. to 7:30 P. M. for the first period; 7:30 P. M. to 8:15 P. M. for the second period; and 8:15 P. M. to 9 P. M. for the third period. Each man had a seating chart in front of him which enabled him to record those seats which were occupied in the first, second, and third periods.

Fig. 1 shows the seating diagram of the theater and black boxes of various sizes indicate in which period the chairs were occupied. Fig. 1 shows the different weights given to the black markings in accordance

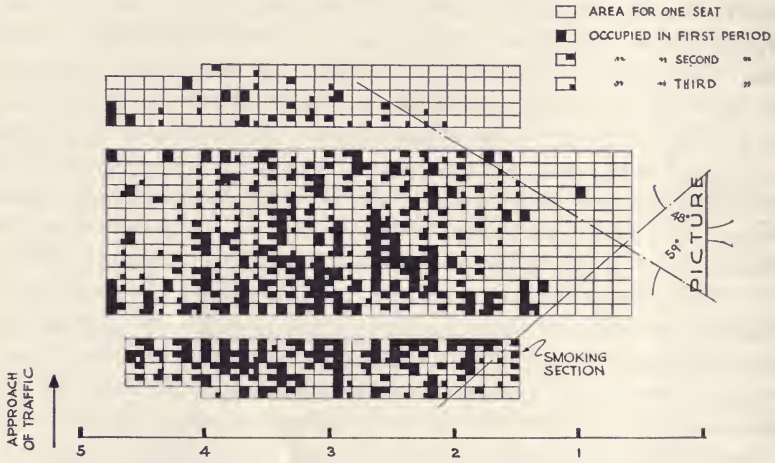


FIG. 1. Theater seating chart for determining preferred seating areas.

with the period when the occupancy occurred. Greater weight was given to the earlier periods so that a visual picture could be obtained of the preferred seating locations. It also assumed, of course, that the chair locations occupied in the earliest period would indicate the highest preference.

In this particular theater the facts that the approach of traffic was from one side rather than from the usual center approach, and that the smoking section was placed to one side threw the weight of preferred seats to one side, as the chart indicates. The picture size in this theater was 12 ft 7 in. × 17 ft 5 in. and the screen illumination was a little above the average in intensity. The picture size was larger than the average size to be expected for the maximum viewing

distance of this theater. The maximum viewing distance was 4.85 × the picture width. In accordance with a previous survey made by this Committee, the average picture size in relation to the maximum viewing distance was found to be the maximum viewing distance divided by 5.2. It is not assumed at this time that this single survey could by any means give conclusive information as to preferred seating arrangements. It would be necessary to make approximately a dozen or more of these surveys under different conditions as already suggested in this report. However, it is interesting to note some of the disclosures made by this survey. These are as follows:

(*1*) That seating locations in an area near the picture starting with the picture and ending with a distance approximately $1^1/_2$ times the picture width away from the picture, are resorted to only very infrequently.

(*2*) That the preferred viewing distances from the picture are found in an area located at distances beginning at approximately twice the picture width and ending at approximately four times the picture width. Fig. 1 is marked with a scale at the bottom to show the relation of viewing distances to the picture width. Each unit marked on the scale is equal to the picture width.

(*3*) That seats located in an area too far to one side of the picture, or such as may be located outside an angle of approximately 60° in relation to the picture surface as shown on the chart, are not occupied any sooner than the two seats heretofore mentioned in the front sections, when other seats are available.

Conditions in this particular theater did not permit any worthwhile observations to be made as to what could be considered as useful seating areas at more remote distances from the picture.

Sub-Committee on Screen Brightness

As reported at the last Convention of the Society, the Sub-Committee formulated provisional specifications for illumination meters and brightness meters and was placing these before instrument manufacturers to determine the feasibility of having them made available. It is proposed to review the results of this investigation in this report. Before doing so, however, it seems desirable to summarize briefly the preliminary conclusions and opinions of the Sub-Committee on which the provisional specifications were based.

The Sub-Committee has felt that instruments for merely measuring total flux in the beam from the projector, or average brightness of

the screen, would be inadequate and that the instruments should be of such a character as to permit determinations of uniformity of illumination and brightness. This introduces no serious problems so far as illumination meters are concerned, but it does mean that, in the case of the proposed brightness meter, the instrument must be designed so that it "sees" only a limited area of the screen at a time. It was also agreed that, if the brightness determinations are to represent a true measure of what the audience sees, the measurements should be made from the seating area and include the extreme seat positions.

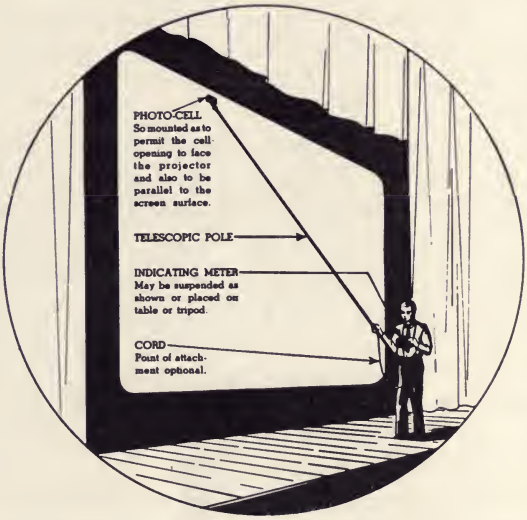


FIG. 2. Suggestion for possible form and use of illumination meter.

Data presented by the Projection Practice Committee in 1938 indicate a minimum angle subtended by the screen of approximately 8 degrees. Therefore, the "angle of view" of the brightness meter should preferably be not more than 2 degrees if a reasonable indication of brightness uniformity is to be obtained from the most distant seats.

If possible, the use of "visual" types of instruments should be avoided because of the difficulty of matching brightness fields with color differences present. The use of photoelectric cells of either the photoemissive or photovoltaic types corrected to eye sensitivity was recommended.

Since measurements of illumination at a variety of points on the screen area are required to obtain a reasonably accurate average value, the illumination meter should be separate from the photocell and connected to it by a suitable length of conductor. Similarly, means should be provided to hold the cell at any point on the screen area without resorting to the use of ladders or other cumbersome equipment.

Since measurements of brightness at a variety of areas on the screen were proposed, at least the "viewing" part of the brightness meter should be swivel mounted on a suitable support, or tripod, and means provided for aiming at specific points on the screen. Also, the aiming device, or "view finder," should probably indicate specifically the field included by the instrument.

To clarify the several points summarized here and included in the letter circulated to instrument manufacturers, two sketches were prepared to illustrate the proposed use of the meters (Figs. 2 and 3). The letter also included a tabulation of the provisional specifications (Table I).

TABLE I

Provisional Specifications for Illumination and Brightness Meters

	Illumination Meter	Brightness Meter
Useful Range of Instruments	0.2–50 ft-candles	0.5–30 ft-lamberts (or 4–30)
Accuracy of Measured Values	±5%	±5%
Reproducibility of Measured Values	±3%	±3%
Max. Screen Area or Angle to be Included by Instruments	1 sq ft	3° (preferably 2°)
Maximum Price	$50	$50

The Sub-Committee's choice of readable brightness values from 0.5 to 30 ft-lamberts was included provisionally to permit measurement of the brightness of the peripheral field should that area be illuminated. The alternative range of values from 4 to 30 ft-lamberts was included if it should be found impracticable to obtain an instrument capable of reading 0.5 ft-lambert.

The values for the illumination meter of from 0.2 to 50 ft-candles were chosen in recognition of the requirement in some states of minimum ambient levels of illumination in theater auditoriums, and

because of the numerous other illumination measurements for which such an instrument could be used in theaters.

The letter to instrument manufacturers also included a request to consider the practicability of an inexpensive amplifier for increasing the sensitivity of brightness meters employing photocells. Since the frequency of the light on a motion picture screen is 48 cycles per second, it was felt that perhaps a 48-cycle amplifier, with a null method of indication, might have advantages.

The general letter outlining the problem and the provisional specifications was sent to 30 instrument manufacturers. Replies were

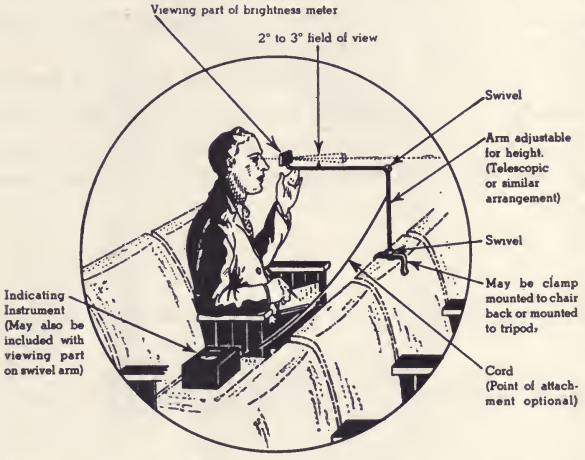


FIG. 3. Suggestion for possible form and use of brightness meter.

received from 20 of these companies. Twelve of them expressed either no interest in the subject or an inability to take action at the present time. The remainder expressed a willingness to coöperate and several submitted helpful suggestions and criticisms. As a result, the Sub-Committee first of all revised the tentative specifications for accuracy and reproducibility of measured results from 5 to 15 per cent and from 3 to 5 per cent.

As anticipated, the attainment of a satisfactory illumination meter seems to present no serious problems. However, the design of the desired type of brightness appears considerably more difficult and the Sub-Committee feels that it should devote its attention to that problem until a practicable design has been found.

Subsequent calculations by members of the Sub-Committee indicate the magnitude of the brightness meter problem. Assuming the use of a collector lens which would also serve to limit the field of view of an instrument employing a photoelectric cell, the illumination at the lens with 4 ft-lamberts on the screen in the 2-degree angle would be 1×10^{-3} ft-candle at any distance from the screen.

A photovoltaic cell corrected to eye sensitivity and used as proposed would have an output of the order of one or two thousandths of a microampere under these conditions. Such currents are too low to read on any convenient, rugged form of instrument and, therefore, the Sub-Committee is extremely doubtful of the practicability of using such cells, unless the tentative specifications are radically altered at the expense of many features now considered to be eminently desirable.

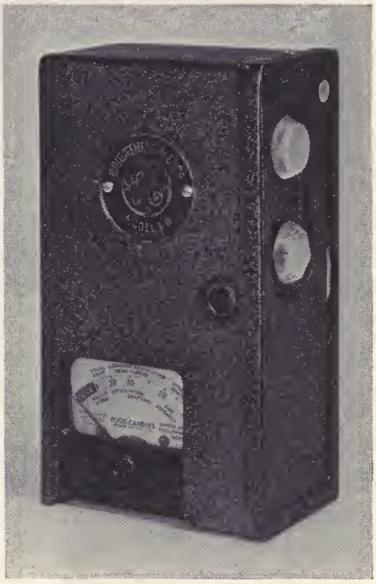


FIG. 4. A simple brightness meter employing a light-meter for the indicating instrument.

The use of the photoemissive type of photoelectric cell presents many difficulties. Under the conditions previously described, an output from the cell of the order of 2×10^{-5} microampere seems likely. While so low an output does not necessarily represent an insurmountable obstacle, it should be evident from the foregoing data that the design of a suitable brightness meter employing either type of photocell would require a considerable amount of development work.

An interchange of ideas between the Sub-Committee and those instrument manufacturers interested in a photocell type of brightness meter continues. In the meantime, however, the Sub-Committee is reconsidering visual types of brightness meters, since one such instrument is already available (Fig. 4) at a price close to the figure considered to be acceptable.

One objection to a visual type of instrument has been the difficulty

of matching fields of brightness when a color difference is present. This can be minimized through the use of color-matching filters. This leaves, then, only the inconvenience of taking a number of readings to average out errors of individual readings, and the fact that such instruments are less convenient to use.

As a further possibility, the Sub-Committee has under consideration a photographic type of brightness meter. Such an instrument would function as a camera with a lens of fairly long focal length, and probably small aperture, that could be used to photograph the illuminated screen from any seat position. Exposures would probably be long—perhaps in the range of ten to twenty seconds.

The camera and film in itself could not be considered as an absolute brightness measuring device; an auxiliary piece of equipment to calibrate the camera and film at the time of its use would be essential. In its simplest form, this auxiliary device might consist of a box containing a lamp illuminating a series of targets to definite brightness levels. This panel box would have to be photographed either when the screen is photographed, or soon before or after, and both images would have to be developed together. The process of evaluating screen brightness and brightness distribution would involve simply comparison of target and screen image density distribution.

There are certain difficulties in the design of such an apparatus. The color response of the film would have to be matched by filters to that of the eye. Precautions to avoid scattered light in the camera would have to be taken. Some convenient means of matching target and screen-image densities would have to be devised. At best the apparatus involved would be cumbersome.

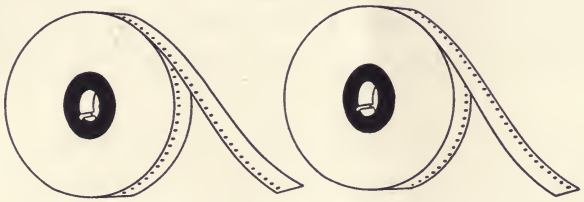
On the other hand, such a device would result in a convenient form of permanent record of test results. In addition, the simplest form of operating instructions would suffice and it is beleived that the specifications of accuracy, angle, range, and price could be conveniently met.

REPORT OF THE STANDARDS COMMITTEE*

The two projects entitled "Designation of Direction of Winding of 16-Mm Film Perforated along One Edge" and "Edge-Numbering Interval for 16-Mm Motion Picture Film" which were stated in our report at the Rochester Convention as being considered as SMPE Recommended Practices have now been approved, and have appeared in the November issue of the JOURNAL.

In considering the "Designation of Direction of Winding of 16-Mm Film Perforated along One Edge" it was evident that there had been some divergence of practice among various companies in designating the direction of winding 16-mm film that would naturally lead to some confusion among those who were handling film from a number of different companies. The designation that has been adopted as an SMPE Recommended Practice is as follows:

When a roll of 16-mm film, perforated along one edge, is held so that the outside end of the film leaves the roll at the top and toward the right, winding *A* shall have the perforations on the edge of the film toward the observer; and winding *B* shall have the perforations on the edge away from the observer. In both cases the emulsion surface shall face inward on the roll. This is illustrated by the following sketch.



Winding *A*
Emulsion side in

Winding *B*
Emulsion side in

This sketch shows film wound on film cores. When the film is wound on a reel having a square hole on one side and a round hole on the other, the square hole shall be understood to be on the side away from the observer.

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* Presented at the 1941 Fall Meeting at New York, N. Y.; received October 20, 1941.

This definition has already been adopted by a number of the large film manufacturing companies.

There were likewise a number of different systems proposed and tried for edge-numbering 16-mm motion picture film. These included placing numbers on the film at 16-frame intervals corresponding to one-foot intervals on 35-mm film, numbers at one-foot intervals on 16-mm film, and numbers at intervals corresponding to seconds of screen time. After considerable study and discussion with various companies of the industry the following SMPE Recommended Practice was adopted:

If 16-mm film is edge-numbered, the interval between consecutive footage numbers shall be 40 frames.

This seemed to give the best solution and also assumes that not all 16-mm film is edge-numbered. It does likewise give the advantage of not having the numbers so close together as would be the case if they were placed at 16-frame intervals.

A project for revising the standards for 16-mm sound-track and scanning area is being considered by the Committee at the present time. Work on the Glossary is progressing and several lists of words have been checked over by the Committee. The question of sprockets has been reviewed and a résumé of the situation on 16-mm sprockets is being compiled. A sub-committee is actively engaged in seeing what can be agreed upon for consideration as Recommended Practice for 35-mm sprockets specifications.

A number of committees of the Society, such as the Sound Committee and the Non-Theatrical Committee, are working on projects that have been referred to them by the Standards Committee.

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SOME EQUIPMENT PROBLEMS OF THE DIRECT 16-MM PRODUCER*

LLOYD THOMPSON**

Summary.—*The production of industrial films by the direct 16-mm method is now definitely out of the experimental stage. As more industrial work is done by this method there is an increasing demand for more and better 16-mm equipment suitable for professional use. Such equipment can be developed successfully only after the professional user has found by actual experience what he needs and wants.*

A number of 16-mm professionals were asked for suggestions as to what is needed. These suggestions combined with the author's own ideas gained over a period of ten years in the professional 16-mm field form the basis of this paper. Some of the ideas presented could be acted upon immediately; some can not be put into practice until the demand for 16-mm service becomes even greater.

A leading motion picture technical journal recently said in its columns, "16-mm commercial filming has long since outgrown the experimental stage and become a legitimate and highly specialized field of professional cinematography. The technicians in this field stand definitely apart both from the 16-mm amateur and from the 35-mm professional fellow."

Today there are several organizations within this country devoted exclusively to producing business and educational films by the direct 16-mm method. While it is true that a great deal of splendid equipment has been built for the 16-mm users during the past few years, there is still a considerable amount of equipment which the commercial 16-mm producer would like to see on the market. I believe that it is realized by most of these producers that some of the things they want will not be placed on the market for some time because there is not enough of a demand to warrant any manufacturer placing it in production. That, however, does not keep the producer from wanting it.

In an attempt to find out what the 16-mm producer would like to have, the writer recently sent a questionnaire to a number of men

* Presented at the 1941 Fall Meeting at New York, N. Y.; received September 10, 1941.

** The Calvin Company, Kansas City, Mo.

throughout the country who were known to be doing direct 16-mm work. It is true that the questionnaire did not reach as many as it might because some of the 16-mm producers have not made themselves well enough known. However, it is believed that the most important of these producers were reached and it is also believed that the most important of them answered the questionnaire. The questionnaire was sent also to others directly interested in direct 16-mm production. It is hoped that this report will help to interest certain equipment manufacturers in placing on the market certain of this equipment wanted by 16-mm film users.

FILM

In making a survey of this type it was natural to begin by asking what improvements were most wanted in 16-mm raw film for pictures, for sound, and for duplicating. It was quite interesting to note that several asked for a 16-mm negative film with extremely fine grain for making original films. This was especially interesting since none of these people followed up their request under the question about laboratory services. In order to use such a negative film, successfully it would be necessary to solve a number of problems connected with using negative film in the 16-mm size. Since it is a poor policy to figure on editing an original negative and making all the release prints from the original negative, it becomes necessary to make a master positive from the original negative, and then make a duplicate negative from that and make release prints on it. In order to do this, it is almost necessary that better cameras and printers be devised in order to keep the picture steady. Better laboratory service must be made generally available if a film is to be put through all these processes and still retain any quality, such as is done in Hollywood.

A number of direct 16-mm productions are now being used with all synchronous sound. This has brought up the need for an edge-numbered 16-mm film for original shooting, a problem that has been before the Standards Committee of the Society and has had considerable discussion. Unfortunately it is impossible to get any except a few emulsions with the edge numbering. There seems to be little agreement as to which films shall be numbered and which shall not be numbered. At least some of the producers feel that all film to be used for original shooting should be numbered. If so, it means that all black-and-white reversal film that is sold should be edge-numbered.

It means that all kodachrome film or other color-film should also be edge-numbered. The producer of direct 16-mm pictures is not particularly interested in whether duplicating films or positive films are numbered, although there are a number of film libraries and other organizations who are interested in having such film edge-numbered. It is argued by the manufacturers that it will be impracticable to edge-number all 16-mm film. It is argued by the producers that it would be useless to number some of the films and not all of them. The reason is quite simple: One of the things that makes direct 16-mm production so versatile is that 16-mm film can be purchased in any part of the country. Therefore, a producer making a picture at anytime in any part of the country can obtain his film at almost any photographic store if he finds that he needs more than he has taken along for the job. Many times the producer finds that it is advantageous to have someone else in some other part of the country shoot certain scenes and send them to him. This keeps production costs low, and since reversal film is so well standardized by the laboratories of the film manufacturers, he can do so and be assured of getting good quality. Many times it is desirable to use several different cameras in photographing certain pictures, and at times it is desirable to use cameras of different types such as the camera that is loaded with a magazine.

If such a picture is to be edited by means of a work print and edge numbers are to be used in the editing, it is almost necessary that all the originals be edge-numbered or the system will be quite useless. If the films have been obtained at different sources or if the pictures have been taken by various photographers in different parts of the country, it is almost necessary that all the film be edge-numbered, otherwise a number of shots will probably be made on film that is not edge-numbered. The writer believes that the day will come when all 16-mm film will be edge-numbered, and at the present time it should be possible to obtain on special order edge-numbered film from any film manufacturer.

It was to be expected that a number of persons would ask for improvements in color-film and a method of obtaining cheaper color-prints. There were some suggestions made in regard to improving color-film but only one request for cheaper color-prints. (Since that time there has been a reduction in the price of color-prints in quantity.) The improvement that seems to be most wanted in 16-mm color-film is an indoor or Mazda-light type of film with a speed com-

paring with that of the fast black-and-white films now available. That is, undoubtedly, a large order but, nevertheless, is something that is wanted. A better treatment for the sound-tracks on color-film would also be desirable.

Several producers expressed an interest in obtaining better quality in release prints; some of the features wanted are sharper prints, better contrast control, finer grain, and better quality in halftones. In the opinion of the writer, a number of these things are laboratory problems instead of improvements in raw film stock. If the proper film stock is used for shooting the original picture, and if it is photographed, lighted, and processed with the thought in mind that it is to be used for making release prints, a great number of these things can be controlled quite satisfactorily, provided the laboratory uses the proper control instruments. A special color-film to be used only for duplicating has recently been placed on the market that will give even better color prints than we have been able to obtain in the past. Improved printing and improved processing technics will undoubtedly give even better results.

EDITING EQUIPMENT

Probably the thing that is lacked most in 16-mm equipment for industrial purposes is editing equipment. All the editing equipment that is available seems to be designed to sell at a price for the amateur users of film, or has been designed or remade from existing 35-mm equipment. Neither type of equipment is entirely suitable for professional 16-mm use. A truly professional 16-mm splicer should be as automatic in operation as possible. It should be accurately made and should be positive in its operations. It should make a straight splice. If such a machine could be sold at a fairly moderate price, a large number of them could be sold. If it can not be made at a moderate price, the sale will probably be somewhat limited, but there are still a number of persons who are trying to find such a splicer at most any price. If the splicer is to be used in editing 16-mm sound-films it should be kept as small as possible. One of the main difficulties with 35-mm equipment that has been converted for use with 16-mm film is that the equipment is so large and bulky and awkward that the editor has a great deal of difficulty in handling it.

Up to the present time 16-mm film is edited somewhat differently from 35-mm film. In direct 16-mm practice the original film itself is many times edited. The person doing the editing does his own

cutting and splicing, all at the same time. It is seldom that the direct 16-mm editor cuts up a work print, splices it together hurriedly with tape, and then has someone go through it and make the splices. More often he is likely to work with the original film, making his cuts and doing his splices all at the same time. In such a case it is necessary that he be surrounded with the proper rewinds, synchronizers, footage counters, sound take-offs, picture viewer, mechanism for projecting sound and picture, and the splicer. Unless the equipment is small and easy to handle it will be very inconvenient for him to work. All the people who answered the question on editing equipment in the questionnaire said that they were using at least some special equipment they had built for editing purposes. A few were using moviola machines. Others were using modified moviolas, and still others were using special equipment they had built themselves. It would be expected that some of the special equipment had been built and was being used because it was cheaper than buying a regular moviola machine. However, that was not always the case, because some of the specially built equipment was considerably more costly than a moviola. There were very few definite suggestions as to how 16-mm editing equipment should be made. The author does not have a great many definite ideas as to how such a machine should be made. The equipment used for editing at The Calvin Company has been built up from a Bell & Howell projector-head and a Victor Animatograph sound-head. This combination was used because it was found that the Bell & Howell head could be attached to the Victor sound-head in such a way that the film containing the picture and the film containing the sound could be very easily threaded up together to run both the sound-track and picture at the same time. It was found also that the drum on the Victor sound projector could be very well used as a machine for picking up separate words from the sound-track. A motion type viewer rebuilt to provide more positive action and avoid danger from film scratches is used for checking individual frames of the picture. A four-sprocket synchronizer and a pair of rewinds that will handle four reels at one time are also used, and a number of small rewinds for handling short rolls of film. It is believed that this equipment would form a good basis for building an editing machine to be used similarly to a moviola. Such a machine would, of course, need a number of refinements, and it would undoubtedly be quite costly to build because it should be built very well and very accurately to protect the original film that must go

through a 16-mm editing machine. While such a machine is certainly desirable from the standpoint of the 16-mm producer, this is probably one of the things that will not be available for some time. The writer recently saw plans for a very simple editing machine that seems to show great promise. There is now one under construction and it should be ready for trial before too long.

CAMERAS

Practically everyone who was asked expressed a desire for a truly professional 16-mm camera. Several of those answering the questionnaire said that they thought the Berndt-Maurer camera would fill the bill and others expressed a desire for certain changes in it before accepting it as the professional 16-mm camera they would like to have.

Many of the producers of 16-mm films are using standard cameras specially adapted to suit their work. Many of the cameras have had special gadgets added to them for special purposes. Some are driven by synchronous motors obtainable on the open market, and others are driven by specially built synchronous motors. A number of them have been blimped for sound, and in this case the blimps have all been made by the users. Recently a blimp for the Kodak special has been placed on the market. We at The Calvin Company built our own blimp several years ago. It was entirely adequate for the sound-recording equipment we were using at that time. However, we installed improved recording equipment and amplifiers some time ago and the blimp we were using was then found unsatisfactory. We constructed another blimp, of different and heavier construction, which has been doing a satisfactory job. However, it is slightly harder to handle, and we should like to have a lighter and more efficient one, or, better still, we should like to have a 16-mm camera for sound shooting that does not require a blimp. At the present we feel that this is the only serious defect in the professional camera being offered.

Many of the pictures we are now making for industrial use are synchronized dramatic shows, and it is necessary that a quiet camera be used in photographing them. Over a period of years we have tried practically all the 16-mm cameras on the market, and during that time we have come to rather definite conclusions as to what we should like in a camera. First, a professional 16-mm camera should be silent enough to be used on the set for photographing syn-

chronous sound pictures without a blimp. If it is not possible to build such a camera, we feel that some convenient and easy method of blimping it should be worked out so that the camera will not become too heavy and difficult to operate. We realize that this is quite a large order but we do not feel that it is impossible.

The camera should have registration pins, and the pull-down claw should be as close to the aperture as possible so that the frame-line will remain steady and centered at all times. The camera should have side-guides to prevent the film from weaving. The shutter should not be connected to the claw because such an arrangement will cause it to run unevenly and produce flicker in the pictures; or some method of eliminating the flicker should be used. The camera should be driven by some type of synchronous motor, which should be connected to the shutter in such a way that the film flow through the camera will be perfectly even and the exposures quite uniform so as to prevent flicker. We have always found that it is easier to get smooth, evenly exposed pictures with a spring-driven camera than with a motor-driven camera. As a matter of fact, we have had a great deal of difficulty with motor drives on cameras.

The film-gate of a professional camera should be constructed in such a way that it is impossible to scratch film. Some cameras on the market hold the film perfectly flat in the camera, but in doing so they quite often scratch the film and produce static. When such a condition exists in a camera we have found that it is impossible to eliminate it completely even though the film-gate is cleaned thoroughly after every 100-ft roll of film. On the other hand, there are some cameras on the market that do not give this trouble, but in these cameras the film will not stay in its proper plane at all times and the pictures are likely to be very much out of focus. The manufacturers are well aware of this, and during the past year have done a great deal to eliminate the difficulty. For the past nine months we have not had any difficulty of this particular sort, but in building a professional camera this is certainly a pitfall that should be avoided by the manufacturer.

As far as we are concerned, such a sound camera can be of the simplest type. It can run at one synchronous speed of 24 frames a second. It need not have an automatic fade or dissolving shutter because we feel that all such effects can and should be made in the laboratory and not on the set.

The camera should have a view-finder that is really accurate and

easily used. It is not necessary that one be able to record sound with the camera because we believe that all sound made in the studio should be made by the double system. It is not urgent that the camera have a lens turret if such a turret would cause any special difficulty in manufacture or would raise the price considerably. On the other hand, there are times when a turret can be used. The camera should have an accurate method of focusing on the film. In short, we want a quiet-operating, synchronous-speed camera that will produce the sharpest, steadiest picture possible.

These are some of our ideas as to what we should like to have in a 16-mm professional camera. They do not necessarily agree with some of the views expressed by others. We believe that most producers want a variable shutter on the camera. They have expressed a desire that the shutter be made automatic, for automatic fades and dissolves, and some have expressed a desire for one that will make wipe-offs. A number have expressed the opinion that a 16-mm professional camera should be able to record sound on the film by the single-system method. It goes without saying that everyone wants such a camera to handle 400 feet of film or more.

There have been numerous rumors during the past several years about companies who were going to make 16-mm professional cameras that would soon be on the market. So far most of these rumors have been pretty consistently denied, although several companies have admitted that they have been working on such a camera. The details of the cameras have been kept secret by the manufacturers. If any manufacturer would care to take us into his confidence, we should like very much to see what he had in mind and help him make a practical test of the camera.

RECORDERS

No suggestions were received for improving direct 16-mm recorders. One person answering the questionnaire said that 16-mm sound should be more faithful and more realistic and should have less boominess. However, this person said that this characteristic was not limited to sound recorded by the direct 16-mm method but was present in nearly all 16-mm film no matter what method was used in producing them. Another person answering the questionnaire said that he felt that 16-mm sound could be made better but that the next improvements were going to come in film recording stock. It is certainly true that the new Agfa high resolving sound recording stock

for 16-mm has shown that improvements in film stock will improve the results in recording. We are of the opinion that a great many persons who are doing direct 16-mm recording are doing their recording in rooms that have not been correctly treated for sound-recording purposes. Much of the direct 16-mm sound that is being recorded is being made by talent that is untrained and unrehearsed. However, we must say that even the talent is continually becoming better. Voice-recording machines are becoming quite popular and common. As a result of this, combined with radio work and picture work, there is continually more talent available and much of this talent works very hard to give better performances. This improvement, together with the best 16-mm recording equipment, developing, and printing, and an improved technic of recording, will naturally be reflected in future pictures.

LABORATORY SERVICES

After the picture and the sound have been put on the film, there is then the problem of properly developing and printing it. Good laboratory service for 16-mm film has been very slow in coming. It is true that the authorized processing stations of the film manufacturers have given fairly good and consistent service on reversal film. They have probably been the most consistent in their work of any of the 16-mm laboratories, but even here there are times when processing standards could be held to closer limits. Even though the service from these laboratories has been good, that still does not answer the problems involved in getting release prints. Very few of these laboratories will attempt to develop sound-tracks made on 16-mm sound-recording film. As a result, the producer of 16-mm sound pictures has been forced to look elsewhere for his laboratory services in developing his sound-tracks and the making of dupe negatives from original reversal film. The answers received on the questionnaire to the question about laboratory services were in one way rather disappointing and in another way they were rather flattering. Most of those who replied to the questionnaire stated that they were perfectly satisfied with the laboratory services they are now getting. This, of course, is very nice for the laboratories to hear, but it was hoped that a number of good suggestions would be made for improving laboratory service. Nearly all those answering the questionnaire stated that they would like to have optical effects available for 16-mm work. Some said that they thought this was too much of a

problem to present to the laboratories at the present time. Others knew about the optical effects that we offer in our laboratories and were very well satisfied with the results they could get by this method. Some indicated that it would be desirable if some method could be worked out so that these effects could be used at less expense. One answer to the laboratory question was particularly interesting. It came from a man who has had a great deal of experience in developing 16-mm equipment and who has had also a considerable amount of experience in laboratory work. I knew the man seven or eight years ago, at which time he told me that 16-mm would never be successful until the laboratories learned how to control and develop the film correctly. Today his suggestion as to the most needed laboratory service is, "Much better work." Although we operate a laboratory, we are inclined to agree with what he says.

The duplication of 16-mm color-film was a distinct achievement. It would be highly desirable if some method could be found for making color-prints by an intermediate negative step so that the original film would not have to be used for making all release prints. We, of course, do not have any idea when such a process will be practicable. Special trick printers have been designed and built for making kodachrome release prints containing optical effects, which will print such release prints with no more trouble than straight printing.

On the other hand, we feel that there is still a great deal of work that can be done on 16-mm printers. Practically all the 16-mm printers that are really doing the best job of printing have been designed and built specially for the laboratories owning them. Anyone desiring to purchase such a printer on the open market will run into many difficulties and become very discouraged before he finds what he wants. There is probably not a great deal that can be done about it, because there is not a large market for such equipment, unless we consider the small laboratories who can not afford to pay very much for it. Such a condition, however, gives 16-mm a bad reputation because there will always be a large number of persons who will try to make prints on equipment that is not adequate, and many of those who see these prints will judge 16-mm by these results.

Some time ago a paper was presented before the Society on the problem of blooping sound-tracks. At that time, there was nothing definite that could be offered for blooping 16-mm film, and as far as we know, nothing has been done about it since. Some sort of black blooping patch that could easily be applied would be the answer to

most of the direct 16-mm blooping problems. There are some, of course, who will not agree, because they will want to work with negative sound-tracks on which a black blooping patch will not work. We believe it will answer many of the problems because a great deal of the direct 16-mm sound is being made for kodachrome printing, in which case either a direct positive track can be made and used or a positive track printed from the negative. In either case the black blooping patches can be used on the edited positive track used for printing. For the person who uses a negative track, some sort of positive should be used for editing the picture. The splices can then be blooped out with the black patch and a re-recording or even a dupe negative made from this edited positive track. The re-recorded track is better for release printing because it can be made all in one piece and of one density for printing. We understand that such blooping patches were used some time ago on 35-mm film, and on several occasions we tried to purchase some of them without any luck. There may be some reason why they are not successful, or it may be that we have not tried to buy them from the correct source. In any event, we should like to be enlightened on this point. We have always painted out all our splices, and we find that that works entirely satisfactorily provided some care is used in painting them out. However, it is a rather slow process and, furthermore, we have had to develop our own painting-out fluid because the fluids ordinarily sold to be used with nitrate film do not seem to work successfully with safety film. It has been some time since we tried the black-out paint obtainable on the market but it is also my recollection that this material was slow in drying. That was not objectionable when only one or two splices were to be painted out, but it became quite a problem when a number of splices were involved. A paint-out fluid should dry very rapidly. It should cover well and should stay on safety film. It should be easy to apply and should not chip or crack.

SOUND PROJECTORS

The question dealing with 16-mm sound projectors was probably the most interesting question in the lot, probably because more persons have had experience with sound projectors than with some of the other equipment mentioned. One hundred per cent of those who answered the questions on projectors said they did not feel that any 16-mm sound projector on the market at the present time was entirely satisfactory from all standpoints. The question was probably

unfair because no piece of machinery will ever be entirely satisfactory from all standpoints in the opinion of all people. One hundred per cent of the replies picked out one brand of projector and indicated that it probably was the best. However, on this same question 20 per cent also included another projector that they thought was very satisfactory. Ten per cent picked a third projector as being satisfactory. One did not answer the question on projectors.

Sixteen-mm sound projectors are today performing very satisfactorily. If all the manufacturers of projectors could get together and combine all the good ideas that have been used on the various machines, one would be produced that would be almost perfect. However, no one manufacturer has been able to do so, and as a result we still have certain objections to various machines. Some of the faults will be found on one machine and some on others. First, we should like to see a machine that will produce sharper pictures on the screen. Much 16-mm film has a tendency to be slightly curly, and since it does not lie flat on the gates at all times, the projected picture will often have fuzzy edges or a fuzzy center. If the film is in perfect condition most any of the projectors will throw a sharp picture on the screen, but there seem to be some machines that are much better in this respect than others. The speed and type of lens used will, of course, affect the situation. A very complete report was given in the July, 1941, issue of the JOURNAL by the Committee on non-theatrical equipment.

We should like better sound from nearly all the projectors. Amplifiers should be better standardized. It seems that there are no two projectors of the same make or of different makes that will play a sound-track and make it sound the same. One can start off across the country with a demonstration reel that is felt to be pretty good and before the trip is half over he will begin to wonder how he ever thought it was a good demonstration reel. Of course, this may be the result of not keeping the projectors in proper operating condition. This is not always so, however, because one can take a batch of new projectors coming from any one of the manufacturers with whom we have had experience and almost always find something that is not adjusted as it should be. Of course, the manufacturer might argue that the dealer or producer selling the machine should see that the machine is in proper operating condition before it is released to the customer. We agree with that, but we think also that the manufacturer should do some training work along this line in order that

the producer and other distributors of sound projectors will be as familiar with the operation of the machine as an automobile dealer's mechanic is with the automobile he sells.

One of the biggest improvements that could be made by all projector manufacturers is to increase the power of their amplifiers. This might, of course, increase the cost and weight of the projector in some instances, but we feel that the increased operating efficiency would make it well worth while. Nearly all the lower-priced projectors give trouble in this respect. Many times sound-prints are blamed for poor sound quality when there is nothing wrong except that the amplifier is being pushed too hard. The use of kodachrome sound-prints has made it even more desirable to have an amplifier of sufficient power.

We feel that all projectors should include a method of focusing the sound-track light-beam for prints of different types. Such devices are available on special order, but should be made standard equipment. One projector has sound-track focusing as standard as a standard feature; the sound focusing is done exactly as in the picture focusing, and it works very well.

Some projectors have trouble with their take-ups and rewinds, others are perfect in this respect. Some projectors still have bad "wows" and others give no trouble at all in this respect although there are some that have some sprocket flutter.

Practically every manufacturer of sound projectors advertises the fact that his projector will not scratch film. We have never found a projector which would not scratch film. We grant that it is quite an engineering problem to produce a machine that will not, under any condition, scratch film, but we still have hopes. Some projectors have gates that are difficult to clean, and others are easy to clean. Some projectors are difficult to thread and others are fairly easy to thread. All projectors should be easy to thread. All 16-mm sound projectors should be quieter in operation. As better sound quality is put on 16-mm sound-tracks quietness will become more and more important.

DISCUSSION

MR. HYNDMAN: Perhaps the law of supply and demand is the real factor facing the 16-mm motion picture producer when he considers the availability of precision equipment to do his work. Manufacturers of 16-mm cameras, sound recorders, printers, projectors, and other miscellaneous equipment undoubtedly

would be glad to supply high-precision equipment if there were a sufficient number of prospective consumers willing to pay the price.

Most of the present equipment meets a volume market demand at low cost per unit to the consumer. Unfortunately, many users of 16-mm equipment fail to appreciate that the construction of high-precision 16-mm cameras, printers, and projectors is just as costly as the construction of similar 35-mm equipment.

It has not been practicable, apparently, for the 16-mm producer to assume the obligation of the cost of design, development, and construction of high-precision equipment because the unit cost would not justify the present returns. When there is sufficient demand for this type of equipment, then the manufacturers, very likely, will supply it at a figure that would be practical to the 16-mm producer.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C., at prevailing rates.

American Cinematographer

22 (November, 1941), No. 11

Gasparcolor Comes to Hollywood (pp. 510–511)	A. Wyckoff
Proving the New Norwood Exposure Meter on Production (pp. 512–513), 539–540)	W. Stull
Corrective Make-Up Can Help the Cinematographer (pp. 514, 540)	J. Dawn
Blue Windows (p. 517)	R. Metty
An Amateur Tries 16-Mm Sound-on-Film Recording (pp. 523, 542–543)	K. O. Hezzelwood

Educational Screen

20 (November, 1941), No. 9

Motion Pictures—Not for Theaters (pp. 383–385), Pt. 31	A. E. Krows

International Projectionist

16 (September, 1941), No. 9

Advance Signs of Reproducer Trouble (pp. 7–8, 11), Pt. II	L. Chadbourne
The RCA 866A/866 M.-V. Rectifier Tube (p. 11)	
Fantasound: A Technologic Epoch (pp. 12–14), Pt. II	W. E. Garity and J. N. A. Hawkins
Theater Television: Some Technical and Economic Aspects (pp. 15–16, 21–26)	A. Hyne

Motion Picture Herald (Better Theaters Section)

145 (November 15, 1941), No. 7

Modern Wiring of Projection Rooms (pp. 33–34)	

SOCIETY ANNOUCEMENTS

FIFTY-FIRST SEMI-ANNUAL CONVENTION

HOLLYWOOD, CALIF.

MAY 4–8, 1942

The 1942 Spring Convention of the Society will be held at Hollywood, Calif., with headquarters at the Hollywood-Roosevelt Hotel. The dates of the Convention closely precede those of the Convention of the National Variety Clubs of America, to be held at Los Angeles, May 14th, 15th, and 16th.

Details of the Convention will be announced in the next issue of the JOURNAL. In the meantime the Papers Committee and the Convention Arrangements Committee are proceeding with plans to make the convention an outstanding one despite the difficulties of the times. It is felt that every effort should be made during the emergency to keep up the technical activities of the Society and the industry, and members are urged to make all possible efforts to attend the Convention.

Special evening sessions will be provided, so as to make it possible for those engaged in the studios during the daytime to attend the technical meetings. Those contemplating the preparation of papers for presentation at the meetings should communicate with the General Office of the Society as promptly as possible.

ATLANTIC COAST SECTION

The meeting of the Section held at the Hotel Pennsylvania on December 11th was devoted to the documentary film. Mr. Irving Lerner, Chairman of the Education Committee of the Association of Documentary Film Producers, Inc., and Mr. Richard Griffith of the Museum of Modern Art Film Library discussed the problems of producing documentaries and traced their development during the past number of years. A film—*A Place to Live*—was shown as a typical example of the documentary film.

PACIFIC COAST SECTION

A special showing of several subjects produced by major studios for the U. S. Signal Corps was held at the Paramount Studio Theater on November 27th. The presentation was supplemented by a paper on U. S. Signal Corps production activities by Major Charles S. Stodter, Signal Corps Liaison Officer.

The subjects shown included *Military Courtesy and Customs of Service, Basic Principles of Skiing, The 60-Mm Mortar Mechanical Training, The Anti-Aircraft Searchlight Battery.* Colonel Nathan Levinson, U. S. Signal Corps Reserve, was Chairman of the meeting.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, the following applicants for membership were admitted into the Society in the Associate grade:

BENHAM, H. J.
RCA Manufacturing Co., Inc.,
Camden, N. J.

BRANCH, RAY
Strand Theater,
Hastings, Mich.

BROWN, C. R.
General Electric Co.,
1 River Road,
Schenectady, N. Y.

ENKE, E. E.
2440 N. Sawyer Ave.,
Chicago, Ill.

GATY, C. B.
Fairchild Aviation Corp.,
88–06 Van Wyck Blvd.,
Jamaica, N. Y.

GOLDMAN, R.
120 Broadway,
New York, N. Y.

LYNCH, W. J.
Hotel Victoria,
51st St. & 7th Ave.,
New York, N. Y.

MARANO, LUIZ
42, Rua do Passeio,
Rio de Janeiro, Brazil

ROBIN, J. E.
330 West 42nd St.,
New York, N. Y.

ROTTELL, I. J.
16128 Wisconsin Ave.,
Detroit, Mich.

TOWLE, P. A.
Box 263,
Marshall, Mich.

UNGERER, J. S. F.
Union Education Dept.,
Union Government,
Pretoria, South Africa

VICTOR, W. S.
376 Harvard St.,
Rochester, N. Y.

In addition, the following applicant has been admitted to the Active grade:

MILLS, B. E.
Mills Novelty Co.,
4100 W. Fullerton Ave.,
Chicago, Ill.

BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted.

	No.	Price		No.	Price		No.	Price
1924	19	$1.25	1926	25	$1.25	1928	33	$2.50
	20	1.25		26	1.25		34	2.50
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	22	1.25		28	1.25		36	2.50
	23	1.25	1927	29	1.25	1929	37	3.00
	24	1.25		32	1.25		38	3.00

Beginning with the January, 1930, issue, the JOURNAL of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers of all issues are available at the price of $1.00 each, a complete yearly issue totalling $12.00. Single copies of the current issue may be obtained for $1.00 each. Orders for back numbers of *Transactions* and JOURNALS should be placed through the General Office of the Society and should be accompanied by check or money-order.

SOCIETY SUPPLIES

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

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

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

Motion Picture Standards.—Reprints of the *American Standards and Recommended Practices* as published in the March, 1941, issue of the JOURNAL; 50 cents each.

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

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

Test-Films.—See advertisement in this issue of the JOURNAL.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

VOLUME XXXVIII • • • FEBRUARY, 1942

CONTENTS

A Frequency-Modulated Control-Track for Movietone Prints
J. G. Frayne and F. P. Herrnfeld 111

Design and Use of Noise-Reduction Bias Systems
R. R. Scoville and W. L. Bell 125

A Precision Direct-Reading Densitometer
M. H. Sweet 148

An Analysis of the Application of Fluorescent Lamps to Motion Picture Photography R. Rosenberg 173

Iodide Analysis in an MQ Developer
R. M. Evans, W. T. Hanson, Jr., and P. K. Glasoe 180

Synthetic Aged Developers by Analysis
R. M. Evans, W. T. Hanson, Jr., and P. K. Glasoe 188

Current Literature 207

1942 Spring Convention at Hollywood, Calif., May 4th–8th 209

Society Announcements 213

(*The Society is not responsible for statements of authors.*)

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A FREQUENCY-MODULATED CONTROL-TRACK FOR MOVIETONE PRINTS*

J. G. FRAYNE AND F. P. HERRNFELD**

Summary.—*A 5-mil frequency-modulated track located between sound and picture areas is proposed to control reproduction in the theater from one or more sound-tracks. A variation of approximately one octave in the control frequency provides a 30-db change in volume range which may be used in part for volume expansion of loud sounds or as noise reduction for weak sounds. The control-track frequency is varied manually and recorded simultaneously with the sound-track in the dubbing operation, the gain of the monitoring channel being varied in accordance with the control frequency to produce automatically the enhanced volume range desired from the release print. The track is recorded in line with the standard sound-track and does not require separate printing or reproducing apertures. It is scanned by a separate photosensitive surface, the output being converted from frequency to voltage variations by a frequency-discriminating network identical to that used in the monitoring channel. The output from the network, applied to the grid of a variable-gain amplifier in the sound channel, controls automatically the volume of the reproduced sound in accordance with that observed in the dubbing operation.*

It is well established that the sound-on-film medium that has been employed since the inception of sound pictures has a limited volume range which is incapable of reproducing in the theater without external aids the range of sound intensities picked up in the recording process. While the recent introduction of fine-grain film has increased the basic signal-to-noise ratio by several decibels the increased volume range thus obtained is still far short of meeting the volume range requirements of modern sound pictures. It is still necessary to expand the volume range by using devices such as noise reduction. In the variable-density method of recording both squeeze-track and printer-light variation are used to expand the volume range further. Experience has shown that by judicious use of these three technics approximately 20 db may be added to the range which is obtained from a sound record made without employing any of these devices.

*Presented at the 1941 Fall Meeting at New York, N. Y.; received October 20, 1941.

** Electrical Research Products, Inc., Hollywood, Calif.

It has been found that even when these technics are employed the volume range is still insufficient for correct reproduction of extremely loud sounds often required to enhance the dramatic presentation of a sound picture, and the resort to overloading of the light-valve is only too common a practice in such situations. To remedy this situation the use of a control-track has been suggested which would produce an automatic change in gain in the reproducing sound system and which would make it possible to reproduce in the theater a range of sound volume comparable to that originally existing on the sound-recording stage. The use of such a control-track makes it possible to eliminate some of the technics enumerated above, especially squeeze-track and printer-light control, and thereby simplifies the operations necessary for producing the enhanced volume range in the theater.

Proposals have been made from time to time for a control-track located on various parts of the movietone print, such as the area between adjacent sprocket-holes, as suggested in British patent No. 473,256 and U. S. patent No. 2,199,559, and currently employed in the Vitasound System.[1] It has also been suggested that the area outside the sprocket-holes on the sound-track side of the print be employed for control-track purposes. The control-track located in the sprocket-hole area is open to several objections. For example, the presence of 96 cycles and its numerous harmonics limits the use of this area to control frequencies well below 96 cps. This permits ordinary manual operation of the controls but prevents the use of any automatic control that might follow the sound envelope frequencies. It is difficult to superimpose multichannel control frequencies on the sprocket-hole track due to the narrow frequency range available below 96 cycles. It is also difficult to record and scan this track in line with the sound-track, thereby requiring separate recording, printing, and reproducing apertures. The location of the sound-track outside the sprocket-holes is also subject to several objections, such as the presence of footage marks and other printed information, the liability to wear and tear, and the accumulation of oil and other dirt which might interfere with the proper functioning of the track in this area. It requires also, in common with the control-track in the sprocket-hole areas, the addition of separate recording, printing, and scanning apertures.

An examination of a movietone print shows that there is an unused area 0.029 inch wide between the inner edge of a standard 76-mil sound-track and the outer edge of the picture frame. Allowing

for an 84-mil scanning aperture in the theater reproducing equipment, which overlaps the 76-mil track by 4 mils on either side, there remains an effectively unused area of 0.025 inch between the scanning aperture and the picture. The control-track described in this paper is located in this area, having the dimensions shown in Fig. 1. The 5-mil width of the control-track was selected only after tests had shown that the output from such a track was ample for all intended

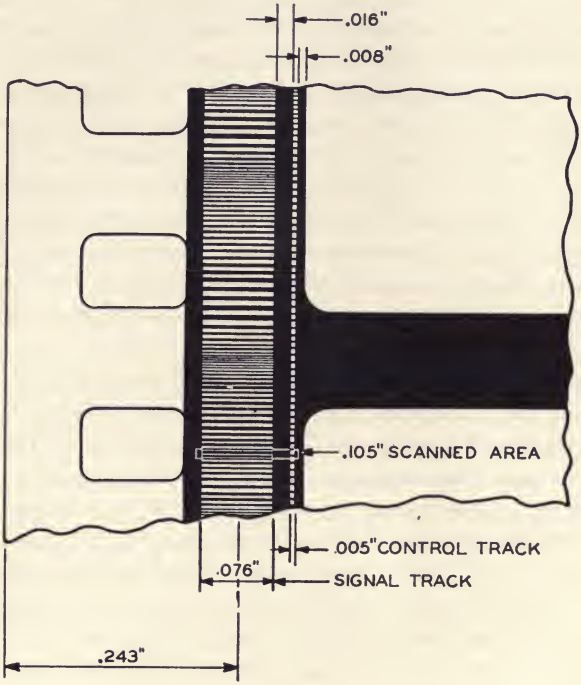

FIG. 1. The control-track.

operations. The location of 16 mils from the sound-track and 8 mils from the picture area was chosen with due regard to established tolerances in printing and reproducing machines. It will be noted that a scanning aperture 105 mils wide is required for proper scanning of the sound and control-tracks. It will also be noted that the sound-track is symmetrically placed between the narrow control-track and the sprocket-holes and is located in the standard position on the film,

thereby permitting playing in a theater not equipped for control-track reproduction.

Amplitude Modulated Control-Track.—In the first attempt to use a control-track in this area, a single control-frequency was recorded, the amplitude being varied manually in the recording process in accordance with the sound level desired from the print. Various single frequencies, ranging from 7000 cycles down to 1000 cycles, were employed at different times, the use of any frequency within this range permitting so-called "fast" operation of the control-track. In reproduction the 5-mil control-track was scanned by a separate photoelectric cell placed in the sound-head, and the output fed into a specially designed logarithmic amplifier. The output from this amplifier was rectified, filtered, and the resulting voltage applied to a variable-gain stage of amplification in the signal channel. Since the signal-to-noise ratio of a 5-mil track is approximately 23 db lower than on a 76-mil track, it was necessary to pass the control-signal through a narrow band-pass filter to secure a sufficiently high signal-to-noise ratio. With a band-pass of ± 250 cycles, a signal-to-noise ratio of 38 db was obtained which was ample for a 30-db range of volume control.

The chief objection to the use of an amplitude-modulated control-track is that the amount of expansion is subject to variations in the output of the control-track photocell, which may be caused by fluctuations in sound-track density, reproducing-lamp intensity, or photocell sensitivity. The amount of expansion is, of course, subject also to accumulation of dirt and scratches on the control-track which tend to vary the transmission of the track. The control frequency is also subject to modulation at a 24-cycle rate by the "burn-over" of the adjacent frame lines. While this effect can be eliminated by insertion of a suitable filter, the operating time must necessarily be limited to values greater than one twenty-fourth of a second. It also requires the construction of rather complicated control amplifying equipment, the characteristics of which depend to some extent on the characteristics of the particular vacuum-tubes employed.

Frequency Modulated Control Track.—For these reasons it was decided to apply the principle of frequency-modulation to the control-track. In this case the frequency to be recorded on the control-track is varied, the amplitude being kept constant, the changing frequency in turn producing the desired changes in loudness of the

reproduced sound. In the reproducing equipment, the frequency variations are converted to amplitude variations by the use of a suitable discriminating network, the rectified output of which is again employed to change the bias in the variable-gain stage of amplification in the reproducing signal channel. Experience with this type of control-track has shown that it is not subject to any of the limitations previously found for the amplitude-modulated track and that it tends to be much more reliable under theater operating conditions.

Method of Recording Control-Track.—Since the control-track is intended for use on the release print, it is recorded during the dubbing operations on the release negative. An *RA-1061* push-pull type light-valve is employed to record simultaneously both signal and control-tracks. The signal is applied to one pair of ribbons and is recorded as a standard 76-mil sound-track, while the second pair of ribbons with suitable masking in the pole-pieces is used to lay down the 5-mil control-track. The various individual tracks are mixed in the usual manner to maintain the proper balance between music, dialog, and sound effects, and ample modulations of the light-valve without overload should be maintained irrespective of the resulting sound volume. The enhanced sound volume, which is heard directly over the expanded PEC monitoring system, is controlled by varying the frequency impressed on the control-track. This frequency is determined by varying the resistance elements of a variable-frequency oscillator which is located in the mixing console. Provision is made for either direct monitoring of the unexpanded signal being recorded or of PEC monitoring of the expanded signal that will later be reproduced from a control-track print.

The control-track may be used either to enhance the volume of loud sounds which normally are compressed due to the limited volume range of the film medium, or may also be used at the other end of the sound-intensity scale to reduce the background noise of the film. Thus, instead of recording low-level passages, as is customary at a low per cent modulation of the light-valve, these passages may be recorded up to nearly top level, and the proper sound balance restored by using the control-track to reduce in proportion the gain of the reproducing channel. In practice it has been found that with a total of 30 db of volume-control range in the reproducing system, the top 20 db of this range may be successfully employed for expansion of loud musical passages and sound effects, normal dialog level being recorded at the 10-db expansion level. To permit increasing

the film modulation for low-level passages, the lower 10-db range of the control-track may be utilized. Thus, it seems feasible not only to expand the louder sounds by as much as 20 db but effectively to

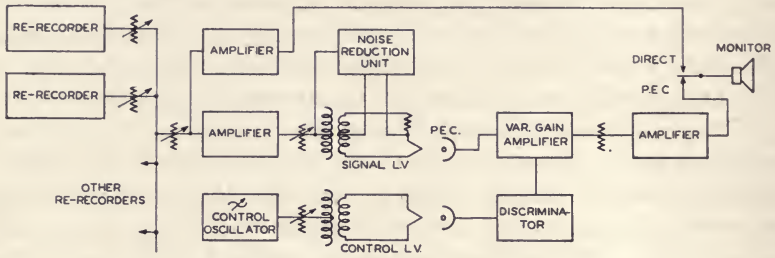

FIG. 2. Re-recording and monitoring system.

reduce background noise during low-level passages by as much as 10 db by the automatic reduction in gain of the reproducing system by this amount through the operation of the control-track.

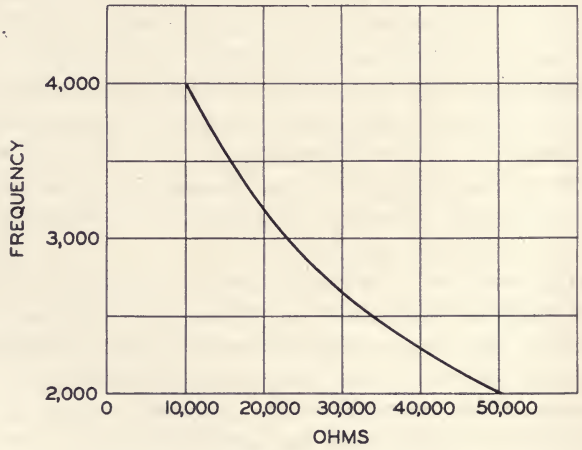

FIG. 3. Oscillator control curve.

Monitoring and Reproducing Circuits.—Since the circuits used for monitoring the expanded volume range in the re-recording operation are identical with those intended for reproducing the control-track film in the theater, it is only necessary to explain their operation in the re-recording process. A diagram of the re-recording and moni-

toring layout is shown in Fig. 2. The outputs from the various re-recording machines are mixed as usual into a single sound channel shown in the drawing. The resulting signal frequencies are amplified and applied to one pair of ribbons in the *RA-1061* valve in the customary manner. Simultaneously the control-frequency generated by a variable-frequency oscillator is applied to the second pair of ribbons of the light-valve. This oscillator may be any one of a variety of oscillators provided that the oscillator used is of such nature that simple controls may be utilized to vary the output of the oscillator from 2000 to 4000 cycles. This particular range of frequency was chosen for the experimental work but any other equivalent range in the sound-frequency spectrum may be equally well utilized. The relationship between frequency and control resistance of the particular oscillator employed is shown in Fig. 3. By

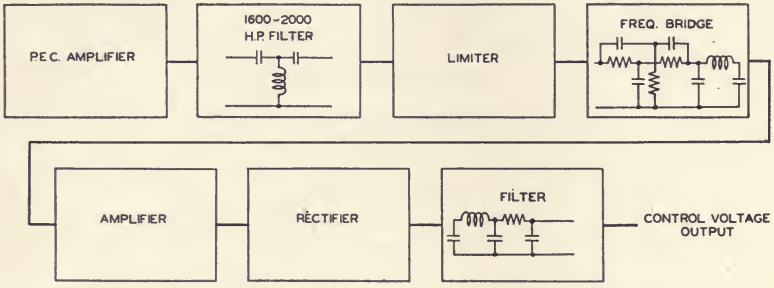

FIG. 4. Discriminator unit.

means of the double PEC monitoring arrangement shown in Fig. 2, the control-track signal is picked up by the second photocell and fed to the discriminator unit shown in Fig. 4.

The output of the control-track is first amplified and then transmitted through a high-pass filter to prevent all extraneous frequencies below the lower 2000-cycle limit from affecting the operation of the frequency-discriminating circuit. The control-signal is next passed through a limiting amplifier employing grid and plate saturation which has an output *vs.* input characteristic as shown in Fig. 5, this limiting action being necessary to insure that the voltage input to the bridge circuit is constant and independent of frequency. This bridge, which is of the type disclosed in U. S. patent No. 2,106,785, assigned to the Bell Telephone Laboratories, is balanced at 4000 cycles and serves as a frequency discriminator to convert the fre-

quency variations to voltage variations. The insertion-loss characteristic is shown in Fig. 6, the loss at the balance frequency amounting to 67 db. This so reduces the output in the operating region that 45 db of gain is required to obtain the necessary voltage for ap-

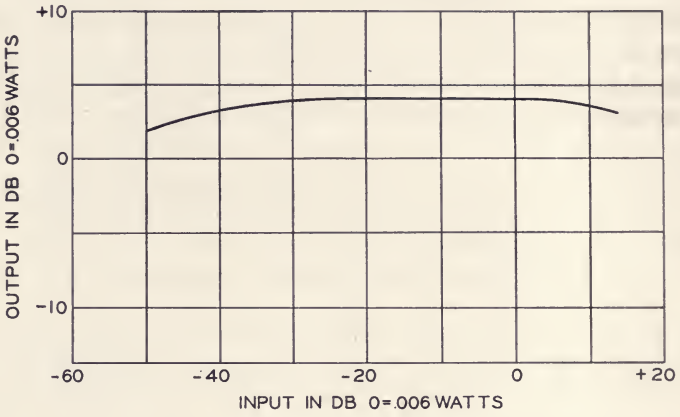

FIG. 5. Limiting amplifier characteristic.

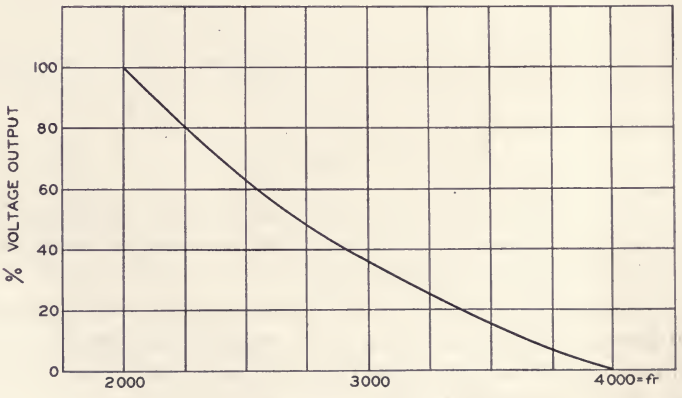

FIG. 6. Insertion-loss characteristic.

plication to the control grids of the variable-mu tubes in the variable-gain stage in the signal channel. The output of the amplifier is rectified and then transmitted through a combined low-pass and R. C. filter to prevent noise and extraneous frequencies above the balance point from being transmitted to the signal channel. The

operating time of 34 milliseconds and release time of 150 milliseconds are determined by the particular filter circuits employed and are not at all critical since the circuit may be used with an operating speed up to 3 milliseconds if so desired.

The output of the signal circuit is fed first into two stages of a resistance-coupled amplifier. The push-pull variable-gain stage follows the pre-amplifier. The gain of this stage is controlled by the biasing voltage applied to the variable-mu tubes from the control-track circuit described above. This bias is fed through a balanced-bridge

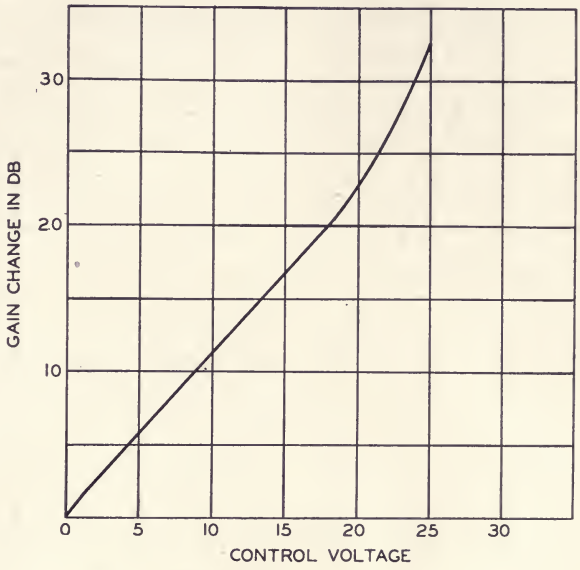

FIG. 7. Variable-mu stage characteristic.

circuit to the control-grids in order to eliminate any residual ripple which may have been transmitted through the filter in the discriminator. In order to permit the use of this amplifier for the reproduction of standard sound-films, provision is made to switch in a fixed bias in the variable-mu stage to replace the biasing voltage supplied from the control-track. The relationship between gain of the variable-mu stage and control voltage is shown in Fig. 7, where it will be noticed that 30 db is obtained from a bias voltage range of approximately 24 volts. The relationship between gain of the variable-mu stage and frequency of the control-track is shown in Fig. 8.

Reproduction Equipment and Circuits.—Since it has been pointed out that the circuits employed in the reproducing and monitoring operations are identical, it will be unnecessary to explain further the operation of the theater expansion equipment, a schematic diagram of which is shown in Fig. 9. The use of identical monitoring and theater reproduction circuits insures that the sound reproduced from

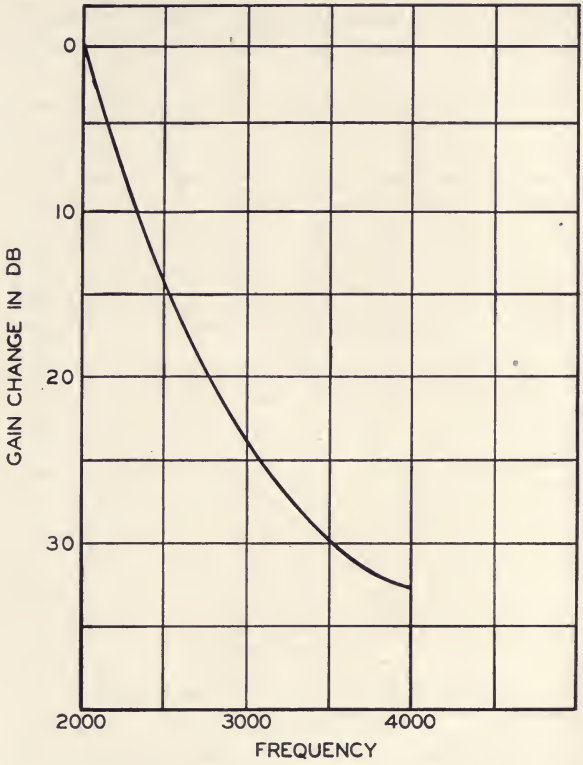

FIG 8. Variable-mu stage gain *vs.* control-track frequency.

the control-track print will have the same degree of expansion as that heard in the monitor during the re-recording process. Certain modifications are, of course, required in the sound-head for proper reproduction of the control-track. For example, the scanning aperture must be widened from the present 84-mil standard to the proposed width of 105 mils. This may be accomplished by widening the physical slit in the reproducing lens system or by increasing the

magnification of the objective lens in the optical system. Fig. 10 shows the modifications to a standard Western Electric *TA-7400* necessary for proper reproduction of the control-track. It will be noted that the light transmitted by the sound and control-tracks is separated into two distinct beams by two abutting lenses, the individual beams being transmitted to the active surfaces of two separate photocells, or the separate surfaces of a push-pull type of cell. If the latter technic is employed, special balancing PEC coupling circuits must be employed to reduce cross-talk between the signal and control-tracks. In certain types of sound-heads, where it might be difficult to mount an additional cell, the use of the push-pull PEC and associated balance circuits is probably indicated. The PEC output from the two tracks is fed over two separate coaxial cables to the special amplifying equipment previously described. The pre-amplifier preceding the variable-gain stage may not be necessary in

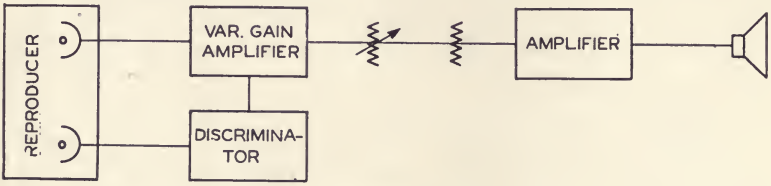

FIG. 9. Theater expansion system.

many theaters having modern single or two-stage pre-amplifiers operating from cable connections from the photocells located in the sound-heads. While the actual physical design and booth location of the special reproducer equipment can not be specified exactly at this time, the circuits employed will undoubtedly be quite similar to those that have been described above.

In reproducing the sound-track in theaters which have not been equipped for reproduction of the control-track, some difficulty may be encountered from audible reproduction of the control frequencies over the theater horn system. This can usually be prevented by readjusting the position of the scanning slit. However, in the case of some of the older optical systems, it may be necessary to insert a mask at the scanning slit to prevent partial scanning of the control-track by the light-beam. In theaters employing modern optical systems, there should be no difficulty provided the lens system is in proper adjustment.

While the use of a single frequency-modulated control channel has been described here, consideration has also been given to the use of multiple channels superimposed on the same 5-mil track. It has been found that three channels each capable of approximately 30-db expansion and suitable for high-speed operation may be accommodated. The number of channels may be increased almost indefinitely if band width and time of operation are not limiting factors. These multiple channels may be used to control the outputs of multiple tracks intended for stereophonic or similar purposes or they may be used, if desired, to switch music or sound effects to multiple horns or

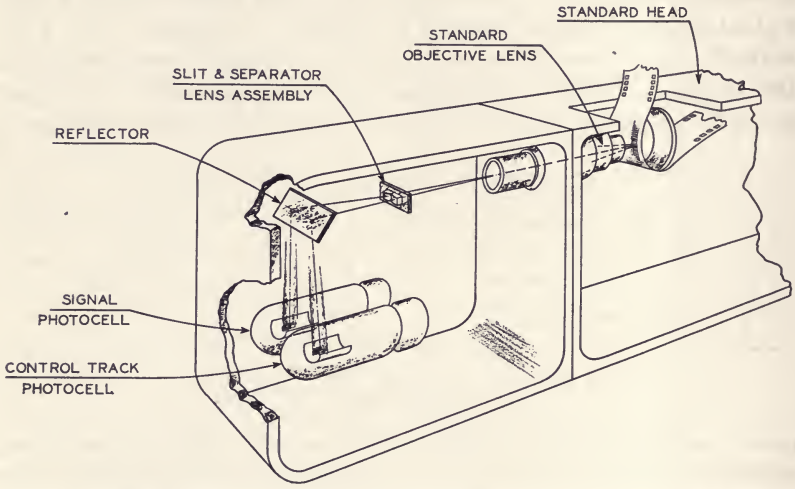

FIG. 10. Modifications in WE *TA-7400* for reproduction of the control-track.

for other similar operations intended to add more realism to the screen.

Recording Results.—The use of this control-track has, to date, been limited to experimental re-recordings of sequences at Universal and Samuel Goldwyn Studios, and the re-recording of a 2-reel musical short at Universal, which is intended for demonstration at the Pantages Theater in Hollywood. In none of these tests was it found desirable to use less than about 12 db of expansion to secure the proper range of sound volume from the print. In others it was found desirable to use the full 30-db range. This was particularly true in the re-recording of a dive-bombing sequence in the picture, *The Long Voyage Home*, in which the top gain was required for proper reproduc-

tion of the bomb bursts and 30 db less gain was required for proper rendition of low-level background music passages. The fact that these extremely loud sounds can be recorded without overloading the light-valve makes possible their reproduction with a degree of naturalness and realism which heretofore could not be obtained on account of the excess distortion incurred from overload of modulator and film.

Conclusion.—It has been found that a 5-mil frequency-modulated control-track recorded between the present sound-track and picture area on the release negative may be used to add 30 db of volume range to existing sound-films. It has also been found that with this device it is no longer necessary to use squeeze-track or printer-light control methods to extend the volume range of variable-density sound-films. The control-track may be recorded in such a manner that a part of the gain change, the upper 20 db, for example, may be employed to enhance the volume of the louder sounds, while the lower 10 db may be used to reduce the gain during the quieter passages; thus adding effectively to the noise reduction during these intervals. The use of the control-track in the area specified is not limited to any particular operating speed nor is it limited to the operation of a single sound channel, but may be used also to provide controls for multiple sound-tracks. In addition it may be used for various other types of control operations associated with reproduction of sound-films. Standard sound-films may be reproduced in theaters equipped for control-track by simply switching in a fixed bias in the variable-gain stage amplifier, and control-track films may be played as standard tracks in unmodified theaters. Experience to date with the use of this track has shown that it may be used very effectively not only to enhance the realism of high-level sounds, but to add much to the dramatic qualities of low-level passages where the usual presence of background noise detracts from the scene being portrayed.

REFERENCE

[1] LEVINSON, N., AND GOLDSMITH, L. T.: "Vitasound," *J. Soc. Mot. Pict. Eng.*, **XXXVII** (Aug., 1941), p. 147.

DISCUSSION

MR. PALMER: Does the use of this proposed control-track involve the addition of new amplifying equipment in the theaters?

DR. FRAYNE: In addition to the modifications of the sound-heads outlined in the paper, the only change contemplated in theater equipment for proper repro-

duction of the control-track is the addition, if necessary, of sufficient amplifier capacity to provide proper reproduction of the louder passages.

MR. KELLOGG: The criticism has been made of any system depending upon changing amplitude of a fixed frequency that it would be susceptible to undesired changes due to variations in exciter lamp brightness and photocell sensitivity (including effect of variations in polarizing voltage). I should like to call attention to the fact that this problem was early considered by H. I. Reiskind who handled most of the development work on the sprocket-hole control-track for us. Following a suggestion of Frank Sheppard, he worked out what has proved to be a very satisfactory way of overcoming this difficulty. Making use of the logarithmic relation between plate current and grid voltage when an amplifier tube is worked in a certain range, he caused the average photocell current to change the amplification so that the 96-cycle output of the tube depended upon the percentage modulation of the transmitted light and was scarcely affected by a change in average brightness of the source, or photocell sensitivity. This work was reported in Mr. Reiskind's paper on "Multiple Speaker Systems" in the August, 1941, JOURNAL.

MR. FARNHAM: Is the picture area affected by the use of the control-track?

DR. FRAYNE: The use of the control-track described in this paper does not call for any change in standard picture or sound-track areas.

DESIGN AND USE OF NOISE-REDUCTION BIAS SYSTEMS*

R. R. SCOVILLE AND W. L. BELL**

Summary.—*The factors underlying the design and use of biased recording systems are described. In order to minimize noise and "shutter bump" special precautions in filtering must be taken. Suitable values for "attack" and "release" times are dependent upon the type of recording, margin settings, and reproducing conditions. Comparison of variable-density and variable-area requirements is made. Methods used in designing the rectifiers, filters, and other circuit details are given and the application to a new equipment known as the RA-1124 Noise-Reduction Unit is shown.*

The reduction of film background noise by the use of biased recording modulators is widely used and the general principles are well known.[1, 2] However, many factors enter into the design and use of noise-reduction equipment which are not so well known. This paper will discuss the subject particularly with respect to variable-density film recording, but much of the information should also apply to variable-area systems.

The improvement afforded by the so-called biased recording method depends upon the fact that noise is reduced when the amount of average light transmitted through the sound print is held to the lowest average value which will still accommodate the desired signal. In variable-density recording this effect is readily obtained by superimposing a bias current on the regular signal current in a light-valve (or similar device) in such a manner as to partially close the opening during quieter intervals. For louder signals the bias current automatically changes in the direction of increasing the average valve opening to an extent which permits the modulator to vibrate without "clash" or overload. No volume distortion of the signal should be caused thereby since the "signal component" of the emergent light is unchanged. Only the surplus light or "d-c component" is altered. Similarly in the variable-area system a bias is used to operate a

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** Electrical Research Products Division of Western Electric Co., Hollywood, Calif.

shutter which masks off portions of the negative film not required to carry the signal amplitude. When printed such masked areas become black and thus reduce noise. Both methods are essentially the same having the common objective of reducing "surplus light." The principle involved is simple but difficulties arise because of two factors:

(*1*) The addition of undesired noise components by the working of the bias current.

(*2*) The time delay between the arrival of a signal and the establishment of the corresponding bias current, which causes "clipping."

(1.0) AUDIBLE EFFECTS PRODUCED BY NOISE REDUCTION

(*1.1*) *Low Frequency Noise.*—The extraneous signal produced by the bias current action must be limited by means of a filter to frequencies so low as to become inaudible over the reproducing loud speakers used. Sensitivity of the ear falls off at the lowest frequencies so that a suitable filter design becomes possible. In practice the design of such a filter becomes a compromise between the amount of noise which can be permitted to come through (see sec. *7.3*) and the desired rate of build-up or "attack" time of the bias current. Obviously the more rapid the "attack" the less will be the "clipping." If the attack is too rapid a "thump" or "shutter bump" will occur when a sustained signal is impressed upon the bias circuit. The use of push-pull records[3] reduces both "thumps" and other low-frequency noise brought in by the bias action.

(*1.2*) *Film Noise Modulation.*—Another form of noise more difficult to deal with is noise modulation or "hush-hush." This is caused by the change in amplitude of film noise at a rate dependent on the bias current. Variable-density recording using film stocks prior to the advent of the new fine-grain types exhibited the effect to a marked degree. For example, piano music was most difficult to record satisfactorily because the envelope of this type of sound is constantly varying over a wide range at rates which pass through the noise-reduction filter circuits. The reproduced film noise as a result rises and falls to produce a disturbing effect sometimes worse than a steady film noise of greater loudness. The term "hush-hush" has frequently been used in reference to the trailing noise which follows up and fills in the gaps in such recordings as piano music. This stands out because it often is not masked by the desired sound. Along with this, and not so generally recognized as such, may be a more rapid noise

modulation proceeding sometimes at rates up to ten or fifteen cycles per second. When recordings of single piano notes are made with biased recording systems there is some "clipping" during the first few milliseconds after each note is struck due to the time lag in the bias circuit. This does not seem to degrade the record quality appreciably, however. The recorded variable-density film may show some "hush-hush" of the type which trails along behind the note but this is generally not very serious. The most objectionable effects are obtained when chords or rapid sequences of notes are played. Examination of oscillograms of this type of sound shows usually a rapidly varying envelope causing the bias current to fluctuate up and down about as rapidly as the filter will permit. The resulting fluctuations of film noise when the print is reproduced can be very annoying. Reducing the amount of the bias fluctuation by lengthening the release time improves the record, but at the same time increases the average noise. Noise-modulation phenomena may occur independently of the bias effect. For example, if a low-frequency signal, such as 30 cycles, is recorded without noise reduction and is later reproduced through a high-pass filter which excludes the fundamental signal an unpleasant sound is heard which is amplitude modulated film noise at the low-frequency rate. The conclusion is evident therefore that noise modulation can be caused not only by the bias action but by the principal sound signals as well. Fortunately, the use of the new fine-grain sound-films[4] greatly reduces the magnitude of these noise-modulation effects so that recordings of the piano and other difficult subjects can be made today very satisfactorily by the variable-density system.

Another method which is quite effective in minimizing noise-modulation consists in the use of "pre and post" equalizers. By this method the higher frequencies are preëmphasized in recording and correspondingly attenuated in reproducing. The overall frequency characteristic is thus not changed but the film background noise is appreciably reduced. Variable-area records generally have less noise-modulation trouble than do variable-density tracks. One reason for this is that in variable-density the noise amplitude varies with the average transmission of the film, whereas in variable-area the noise amplitude varies with the square-root of the transmission. Another contributing factor is that the graininess of a variable-area track is less than that of a corresponding density track. These advantages of the variable-area track are, however, to a considerable

degree offset by other types of noise caused by the presence of dirt, grease, scratches, pin holes, *etc.*, which are more detrimental to area than to density tracks.

(*1.3*) *Volume Distortion Due to Film Characteristic.*—The forms of clipping described above are usually thought of as applying only to the modulating device. However, such clipping is considerably exaggerated at times by a non-linear film characteristic in variable-density recording. This occurs where the straight-line relationship between print transmission and negative exposure does not extend over a sufficiently long range. In the regions of low exposure to the negative the print transmission may become excessively dark and consequently the lower volumes are unduly reduced in amplitude. This may result in the record's having an explosive quality wherein the higher volumes are reproduced too loud in reference to the lower volumes. It may also give a feeling of deadness to the recording owing to the fact that reverberation and other low-volume effects are unduly attenuated. These effects are also caused by an overall gamma which is too high. An excessive setting of noise-reduction bias current also often gives this effect. One of the most satisfactory tests for the amount of noise reduction which is permissible is that furnished by the intermodulation test.[8] This is made by making such a test at a signal level 10 or 12 db below full modulation, with the noise-reduction system operating. Under such conditions the percentage intermodulation should not greatly exceed that used for the normal full-modulation test.

(*1.4*) *Clipping.*—Ideally, noise-reduction bias currents would be applied by interposing a time delay in the speech circuit. Thus, there would always be sufficient carrying-capacity in the modulating device to accommodate the signal. Practically, this has not thus far proved feasible. A method has been developed called the "direct positive"[5] which has the equivalent of anticipation but as this does not provide a negative and is not applicable in variable-density work, the method has not been very generally accepted.

The type of clipping exemplified by single piano notes is to be expected in the usual type of recording, but in general no serious distortion results therefrom.

A more serious form of clipping is incurred with sounds such as illustrated in Fig. 1. The upper trace represents the bias current and the lower shows the sound-wave, in this case speech. Here the time-lapse between successive peaks in the envelope is sufficient to permit

the bias current to release so that the oncoming succeeding peak is clipped and a whole progression of clipped peaks consequently results. The best way of avoiding this type of phenomenon is to make the release time long enough to carry over from one peak to the succeeding peak. In practice this becomes a matter of making the release time as long as possible without unduly increasing the film surface noise owing to the greater average opening which is thereby present. Fig. 2 shows a more suitable bias action in which a longer release time is used. The figures are sketches made from actual oscillograms, for better clarity of reproduction.

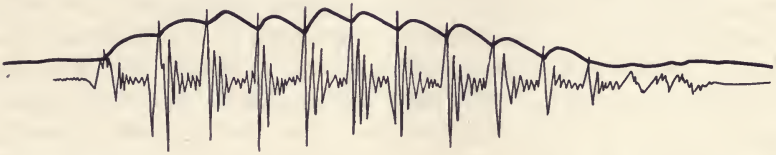


FIG. 1. Bias action and clipping when release time is too short. (*Lower trace*) speech; (*Upper trace*) bias current.

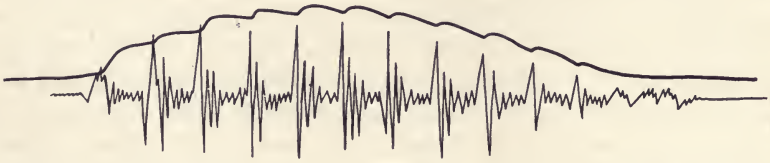


FIG. 2. Bias action with sufficiently long release time. (*Lower trace*) speech; (*Upper trace*) bias current

(2.0) TIMING CHARACTERISTICS

Attack time is arbitrarily defined as the time required for the bias current to undergo 90 per cent of its total change when a signal having a magnitude somewhat less than the value required to cancel the bias fully is applied to the noise-reduction unit.

Release time is defined as the time required for the bias current to undergo 90 per cent of the change when the input signal applied as in the previous definition is removed.

These definitions of the time-constants referred to in this discussion may not be comparable to the time-constants of filter sections described by others. Thus, in speaking of the time-constant of a capacity-resistance filter a value of $C \times R$ is frequently given as the time-constant. This represents the time required for the change to

proceed 0.63 or $(1 - 1/\epsilon)$ of the total amount rather than the 0.90 factor stated above.

For variable-density recording of a single track using 10 db of noise reduction, an attack time of 20 milliseconds, as just defined, has been found generally satisfactory. Some studios, particularly those favoring a heavy low-frequency end, use up to 24 milliseconds while others work with as little as 15 milliseconds.

Margin is defined as the difference in decibels between the applied signal amplitude and the amplitude which the signal could have if 100 per cent modulation of the available spacing were used. In line-up work, margin is generally taken to be the difference in decibels between the signal which just overloads the modulator and the signal which just cancels the bias current (or adjusts it to the final value).

The attack time is the same for all values of input signal up to the value which just cancels the bias. If more than this input amplitude is impressed upon the noise-reduction unit the rate of change increases proportionally to the input signal but since the total change must remain the same a decrease in attack time results. Thus for 6 db of over-cancellation (margin) the attack time is reduced to half.

In order to minimize clipping the attack time is made as short as possible. The limit is determined by the "thump" obtained when a sustained signal is suddenly impressed. The loudness of the "thump" appears to be proportional to the rate of change of the average print density. On this basis the "thump" is loudest on maximum signal amplitudes and becomes less audible as the recording level decreases.

In variable-area recording a somewhat different condition exists. For 10 db of noise reduction the space occupied by the clear area of the print must be reduced to 10 per cent of its normal width. This compares to variable-density recording in which light-valve spacing is reduced to about 32 per cent of normal. If it is assumed that the same rate of change of print transmission is tolerable for both systems, the attack time should be longer for area in the ratio of 90 to 68 per cent, or 1.32. Owing to the reduced initial spacing employed in variable-area recording a greater margin is needed than for variable-density. Thus, 4 to 8-db margin is often employed in area systems. Assuming for computation that only 2 db more margin is needed for area than for density, a correction factor of 1.25 would express the ratio of tolerable attack time for area compared to density on the basis of margin only. Combining this correction with that due to the difference in amplitude of change described above would result in a total time of

$20 \times 1.32 \times 1.25$, or 33 milliseconds for variable-area. This represents the attack time for input signals which do not quite cancel the bias. For the maximum input signal, the time drops to about 20 milliseconds.

In a well balanced push-pull recording system the "shutter bump" and other noise components in the bias system are balanced out so that a faster attack time becomes feasible. Since clipping is reduced by faster attack, there is an advantage in so adjusting. However, some users have preferred to keep the timing the same for push-pull as for standard so that if only one of the two tracks is played, satisfactory reproduction will be obtained. In this case then, the only advantage which push-pull gives over standard recording is in the reduction of harmonics and some bias noise. A push-pull attack time of 8 to 10 milliseconds has proved very satisfactory for most push-pull recording work. The release time for push-pull density recording is generally the same as that employed with single-track recording.

The choice of release time is a compromise between the greatest reduction of noise on the one hand and freedom from bias action and clipping on the other. The longer the release time is made the less danger there is of clipping, since the spacing of the modulating device is held open longer, awaiting the arrival of oncoming wave-trains. Also, a long release time insures a reduction of the working of the bias current thus further reducing miscellaneous bias noise. However, the long release times cause more noise to be present during the interim periods than would otherwise occur. In variable-density systems long release times have not been favored on this account. Another factor which enters is reverberation of the room in which the recording is made. Where considerable reverberation is present, there is no necessity that the bias current die down quickly since the sound in the room does not die down quickly. Theoretically, therefore, the release time would vary with the reverberation time but since this is a somewhat impracticable adjustment to be made a compromise is taken which seems to give the best operation for most types of recordings. In variable-density a release time of 40 to 50 milliseconds appears to be a good compromise. In variable-area recording a longer value of about 150 milliseconds has generally been preferred because the danger of clipping seems more serious with shorter times than is the case with density.

The use of fine-grain films for variable-density sound may make

release times longer than 50 milliseconds desirable but inadequate data are thus far available on this point. The long release time has the advantage that simpler types of filters can be used than for short release systems, reliance being made upon the long release time to provide the required degree of filtering.

(3.0) SHAPE OF ATTACK AND RELEASE CURVES

Where simple capacity and resistance filters are used, the shapes of the attack and release curves obtained are exponential. Where full-section inductance and capacity filters are used slightly under-damped, the attack and release curves are more nearly linear, as in *A*

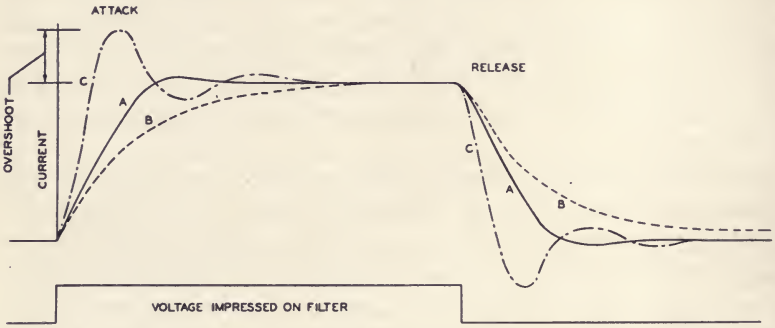


FIG. 3. Characteristic attack and release curves of constant-*K* type filter when a current pulse is impressed. (*A*) For under-damped condition but no overshoot. (*B*) For critical damping. (*C*) For serious under-damping with excessive overshoot.

of Fig. 3. It is of interest here that such filters if critically damped are exponential as in the first case. When not critically damped, however, an additional component is added having an oscillatory characteristic which has the effect of more quickly building up the attack current to its full value, generally with some slight overshoot. This is illustrated in curve *C* of Fig. 3 for a badly under-damped case. The question has frequently been brought up as to whether the shape of the attack curve should be exponential or linear. The answer is that the shape has a characteristic relationship to the filtering efficiency and the one can not be changed without affecting the other. Thus, for any given "attack" and "release" time the most effective filtering is obtained with full-section *K* or *M*-type filters slightly under-damped and these are inherently more nearly linear than exponential. This is further discussed in the section on filtering. In variable-area work

the exponential shape has generally been used with satisfactory results, whereas in variable-density the linear shape has been more common, largely because of the characteristics of the filters used.

The shapes of both the attack and release curves are altered by the amount of margin (over-cancellation) used. Thus, the attack time is reduced by an increase in margin as previously discussed and the release time is increased. The release characteristic exhibits the valuable feature of remaining fully open for an appreciable period after the cessation of the over-cancelling signal, after which it falls off normally. The preferred shape of the release characteristic would seem to be exponential. This is because the noise should fall off uniformly as the release period progresses. A small change in modulator current near the end of the release period makes a relatively large change in noise and therefore the rate of change of current should be rapid

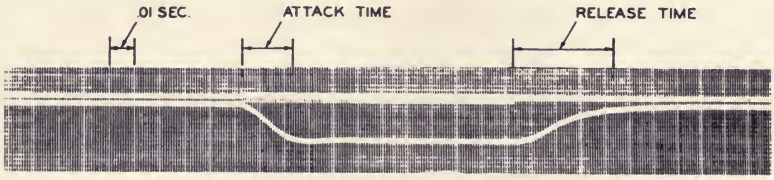


FIG. 4. Typical oscillogram of attack and release currents considered suitable for variable-density single-track records.

at the beginning of the release period and progressively smaller as it reaches the end. This effect is obtained by the use of a capacity-resistance type of filter or the combination of a capacity-resistance filter and an M or K-type section, as will be further described later. Fig. 4 shows an oscillogram of the way in which current builds up and releases with such a circuit suitably adjusted. This is considered to represent the most desirable form, at least for variable-density recording.

The transient effect present due to under-damping of the circuits (illustrated in Fig. 3) is arbitrarily held to less than a 5 per cent overshoot. It is doubtful whether there is any particular disadvantage in a moderate overshoot.

(4.0) NOISE REDUCTION AND MARGIN

The term *Decibels Noise Reduction* has been quite widely used, particularly in the variable-density system. It indicates the expected re-

duction of background noise by the use of bias currents. In variable-density systems the noise output varies approximately linearly with the mean projected transmission of the sound-track, thus:

$$\text{Db Noise Reduction} = 20 \log \frac{T_0}{T_b}$$

where T_0 is equal to the mean transmission of the print in the unbiased condition and T_b is equal to the transmission of the film when the bias is applied. Since the transmission of the print is proportional to the exposure of the negative, one may substitute for the transmission the corresponding spacings of the modulating device with and without bias current, respectively.

The variable-area noise output varies in proportion to the square-root of the clear track width so that here:

$$\text{Db Noise Reduction} = 10 \log \frac{S_0}{S_b}$$

where S_0 is the width of the clear area of the print in the unbiased condition and S_b is the width of the clear area when the bias is applied.

These expressions indicate, for example, that with 10 decibels of noise reduction, 10 per cent of full opening in the variable-area system would be used, whereas in the variable-density system 31.6 per cent would be used. In practice, the bias for variable-area systems is generally set in reference to the width of the bias line rather than by referring to decibels of noise-reduction.

The amount of noise-reduction and margin used at the various studios employing the variable-density recording method varies over a considerable range. This is shown in Table I.

TABLE I

Average Settings of Noise-Reduction Equipments Variable-Density Method

Type Record	Margin	Noise Reduction Used	
		Range	Average
Single-Track Original Dialog	2–3 db*	10–13 db	12 db
Single-Track Original Music	4 db	8–9 db	8 db
Push-Pull Original Dialog	$^1/_2$–3 db	9–13 db	14 db
Push-Pull Original Music	$^1/_2$–3 db	10–18 db	14 db
Single-Track Release	2–6 db	10–13 db	12 db

* These values apply to studios using peak type noise-reduction units. The older average response type units employ 4 to 6 db margin.

The values shown represent total noise-reduction and include that portion obtained by the reverse bias method. The latter method is explained as follows: A nominal amount of noise-reduction is computed on the basis of closing the valve down from the zero bias condition, as, for instance, 8 to 15 db. A further bias in the reverse direction is provided so that on signal amplitudes larger than average the bias current is made to open the light-valve from 3 to 6 db (50 to 100 per cent) further. This opening increase is generally permitted to intrude in exposure upon the non-linear portion of the film characteristic and is sparingly used in recording. Since the overload characteristic of film is gradual the harmonic distortion incurred by so doing is not great and an appreciable increase in "ceiling" is thus obtained.

Many users of the Western Electric variable-density system prefer the push-pull method for all original recording. On dialog only about 2 db more noise-reduction is used here than for standard recording, whereas on music about 6 db more noise-reduction is obtained. The reduced distortion is considered of greater importance than the increased noise-reduction obtainable. The margin used varies from about 1 db to as much as 6 db with an average of approximately 3 db.

(5.0) PEAK RESPONSE CHARACTERISTICS

Some of the older noise-reduction equipment used for variable-density work had a bias current output characteristic proportional to the average value of the input signal. It was found feasible in later circuits, though at some cost in simplicity, to make this response proportional to the peak value of the input signals. This characteristic proved superior to the former one, because many sounds have highly peaked wave-shapes. Whereas a margin value of about 6 db had been necessary with the older-type circuits, a margin of 1 or 2 db appeared to be equivalent with the new. In order to obtain this peak response feature a relatively low-impedance circuit drives a rectifier, as in Fig. 9. This charges up a condenser (C_0) in a time of 1 millisecond or less. Since this condenser must remain charged for an appreciable length of time wherein the bias current output may build up to the required value, a further specification calls for a relatively long release time of discharge of the said condenser. Therefore, the resistance R is made large compared to R_0 in the figure. A ratio of approximately 100 to 1 in the discharging and charging impedances of this storage condenser seems desirable. Since then the ratio of the terminating resistance and the generator resistance is large a very poor power transfer efficiency

is obtained in such circuits. In other words, only about 4 per cent of the energy fed to the rectifier can be utilized in final output. This need not necessarily be a serious obstacle to the use of such circuits since the rectifying may be done in relatively high-impedance low-level grid circuits, the voltage output of which is subsequently amplified.

(6.0) FULL-WAVE VS. HALF-WAVE RECTIFICATION

Experience in variable-density recording has seemed to favor the use of full-wave rectification though some users of variable-area have preferred the half-wave scheme.[2] It is granted there is no necessity of bias action except on peaks which tend to close the modulating aperture, and some have argued that the bias should change in response only to such peaks as tend to close the aperture. The point is also made that most speech waves are dissymmetrical with the highest amplitude peaks nearly always on one side of the wave. Consequently, such signals may be polarized, it is said, so that the largest amplitude always produces an opening of the modulator, a direction in which bias current is of no importance. The peaks on the other side of the wave are then permitted to operate the half-wave rectifier to produce the necessary change in bias current for the small amplitude half of the wave. Although this method apparently has been made to work satisfactorily in some recording systems, there are several disadvantages which have thus far prevented recommendation of the scheme in Western Electric Sound Systems. Some of these objections are as follows:

(*1*) Accurate poling of the microphone is required. This poling, although often reliable, is sometimes reversed by the nature of the pick-up material and by reverberation in the room. Also, it is somewhat difficult to determine with some recording systems.

(*2*) Low frequencies are less adequately filtered in the noise-reduction circuit. A full-wave rectifier doubles these frequencies and renders them more readily removed by the filter in the circuit. Curves *A* and *B* in Fig. 5 show the comparative transmission of noise frequencies through the filter for full-wave and half-wave rectifiers, respectively. In variable-density recording where both low attack and low release times are required in order to avoid hush-hush the filtering is often a very critical factor.

(*3*) Use of the full-wave rectifier may often give an effective head start to the bias build-up since it starts the bias acting in advance of actual need. Thus, some reduction in clipping may be obtained over the half-wave system. The idea of poling the light-modulator so that the highest amplitude peaks open the device is undoubtedly to be recommended even where full-wave rectifiers are used. By so

doing a greater margin of freedom from clipping is obtained, but if the dissymmetry reverses for any reason there will be no damage done. Few if any users of light-valve systems employ this poling technic at the present time, probably because the slight improvement gained is considered not worth the trouble.

(7.0) CIRCUIT CONSIDERATIONS

(*7.1*) *General Design.*—The design of the circuit to be used for noise-reduction bias systems depends upon the impedance of the modulating device and the current requirements. Where the modulator has a medium or high impedance with a resulting low-current

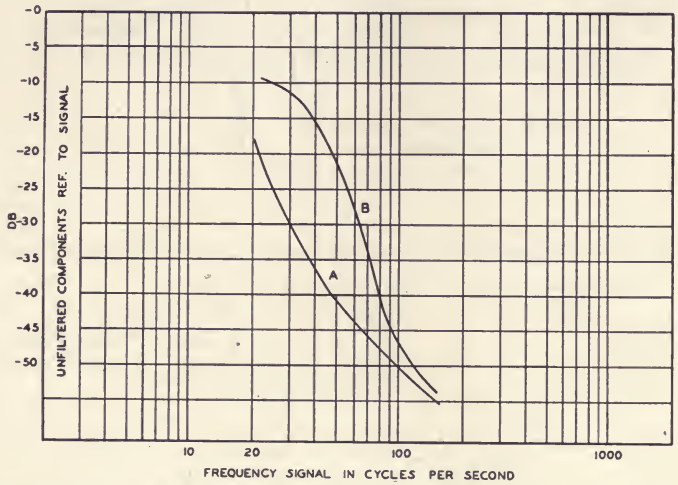


FIG. 5. Comparative filtering effectiveness of using (*A*) full-wave and (*B*) half-wave rectifiers with associated network for noise-reduction bias.

requirement, it may be operated directly in the plate-circuit of a vacuum-tube or out of a copper-oxide rectifier.

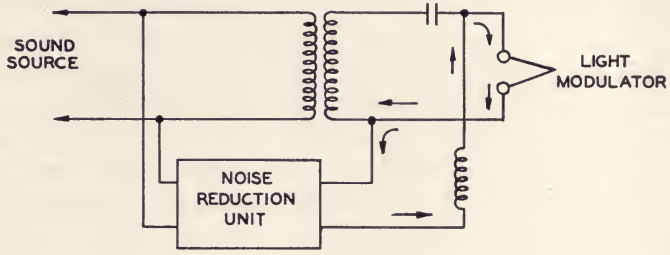
Where very low-impedance modulators are used it is not practicable to use plate-current directly for bias owing to the large current required. The use of copper-oxide rectifiers also presents difficulties for the following reasons:

(*1*) The filters must be in low-impedance circuits so that the values of capacity required become hundreds and even thousands of microfarads which are difficult to obtain. Electrolytic condensers have been used but have disadvantages.

(*2*) The peak response feature which necessitates a short attack and a long release time is difficult to obtain effectively in copper-oxide circuits.

The best solution for the low-impedance case seems to be the use of a modulated high-frequency carrier signal, the output of which is caused to vary in accordance with the peak value of the signal wave. A circuit of this type is described in Sec. *8.0*.

The method of connecting the bias output to the modulating device becomes important where signal and bias are simultaneously impressed on a common modulator. One method is shown in Fig. 6 in which a blocking condenser is used to prevent the direct current from



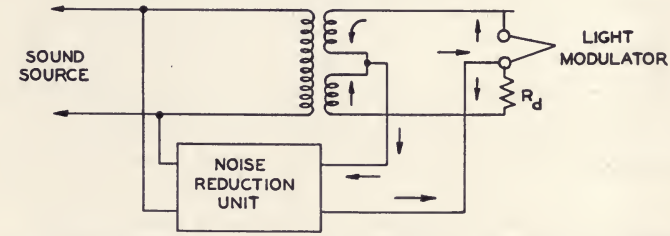


FIG. 6. (*Upper*) Early method of combining bias and signal currents.
FIG. 7. (*Lower*) Simplex method of combining bias and signal currents.

passing through the transformer winding. This method has two objections:

(*1*) The condenser must have several thousand microfarads capacity where low-impedance modulators such as ribbon light-valves are used.

(*2*) The impedance of the bias circuit must be high to avoid shunting the signal circuit by the rectifier in the bias system.

A better method is that shown in Fig. 7 and generally known as a simplex circuit. The circuit is balanced by use of the dummy resistor R_d, which is made equal to the resistance of the light-valve. In this way the bias and signal circuits can have no undesirable reac-

tions upon each other. The simplex method requires twice as much current from the bias circuit as the valve alone requires and the net impedance is half. Thus, for the usual single-track light-valve systems the impedance is only about one-half ohm and the current requirement is in the neighborhood of 500 ma, where both direct and reverse bias are used.

In push-pull systems the dummy resistor may be replaced by the second light-valve.

(*7.2*) *Design of Filter Circuits.*—The simplest type of filter consists of a capacity on the output of a rectifier discharging into a resistance. This type of circuit, which has been analyzed by Kellogg,[6] can be made to give any attack or release time and has an exponential build-up and release characteristic. Its chief disadvantage is its relative in-

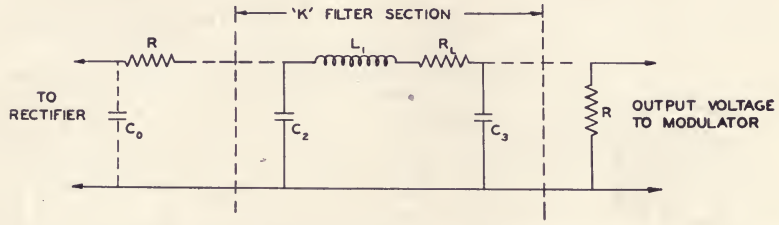


FIG. 8. Constant-*K* filter with suitable capacity-resistance input network for noise-reduction filtering.

efficiency in filtering out unwanted noise components in the bias current as compared with inductive-capacity types of filters. This feature may not be a sufficiently important reason to discredit the simple capacity-resistance filter where it is possible to use relatively long release times.

The constant-*K* type of filter section,[7] as in Fig. 8, gives excellent filtering efficiency and has been extensively used in variable-density systems. When terminated with equal input and output impedances the attack and release times are equal, an undesirable condition as pointed out previously. However, this can readily be overcome by adding a section of capacity-resistance filtering as shown in Fig. 8. Here the input and output impedances are the designed values for the *K*-type filter-section but the timing is modified by the input capacity C_0 in a useful way. If the generator impedance R_0 is small compared to the circuit impedance R and also if R_0C_0 is small compared to the attack time of the *K*-type filter-section, the effect of the condenser

C_0 may be disregarded in its effect on the total attack time. It will, however, have a marked effect on the release time since the discharge of this condenser must be through the two resistors of value R and the filter elements. Where the product of C_0 times $2R$ is large compared to the release time of the K-type filter the value of condenser C_0 becomes almost the sole determining factor for the release time and the shape of the curve is exponential, as is desirable. This circuit also lends itself to peak response action since the condenser C_0 may be made to charge up very rapidly and to hold a charge while the final output voltage is building up in the remainder of the circuit.

If a standard design of K-type filter, as illustrated, is used in which C_2 equals C_3, an oscillatory condition will generally be obtained. In order to damp this circuit satisfactorily, resistance may be added

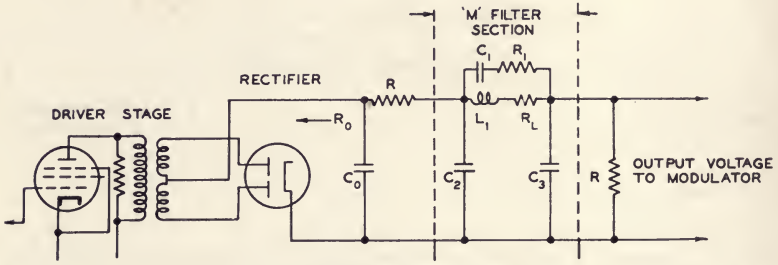


FIG. 9. Modified M-derived filter with capacity-resistance input network as used in *RA-1124* type noise-reduction unit.

in series or across the inductance or in series or across each condenser. However, a more desirable method consists in distributing the capacity unequally between C_2 and C_3 so that the ratio of the capacity between the two is 3 or more as required for damping. It makes no difference here which of the two condensers is the larger.

The K-type filter has a disadvantage in that the attack period is generally rather slow in commencing after the arrival of a signal. To overcome this a condenser by-pass across the inductance may be applied with a suitable resistance in series to damp out the transient otherwise introduced at this point (see Fig. 9). This was found to improve the starting characteristic greatly, as shown in Fig. 10, and also to give a more desirable filtering characteristic because the resonance frequency of the parallel circuit could be adjusted to that value where additional filtering is chiefly needed. This is generally at about 50 cycles. It is apparent that this type of structure is very

similar to an M-derived type of low-pass filter[7] in which the frequency of "infinite" attenuation is about 50 cycles and the cut-off frequency about 25 to 30 cycles. Thus the following expressions give the design values for the elements:

$$L_1 = \frac{mR}{f_c}$$

$$C_3 + C_2 = \frac{m}{\pi f_c R}$$

$$C_1 = \frac{1 - m^2}{4\pi f_c R m}$$

$$m = \sqrt{1 - f_c^2/f_\infty^2}$$

where R = circuit impedance
C_1 = capacity across series arm
f_c = cut-off frequency
f_∞ = frequency of "infinite" attenuation
$C_3 + C_2$ = total shunt capacity of the section

Here C_2 and C_3 may be divided so that approximately one-third of the total is placed at one end of the section and the other two-thirds at the opposite end as required for suitable damping. It should be emphasized that this circuit is not critically damped but is under-damped

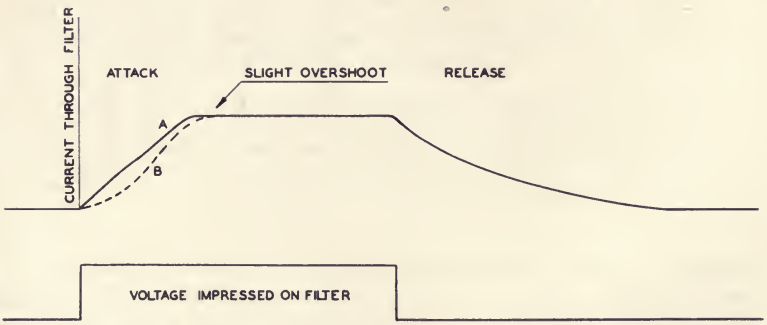


FIG. 10. Showing how use of capacity (A) across series inductive arm of filter improves attack curve as compared with K-type filter (B).

to an extent necessary to give an approximate linear attack characteristic. The value of resistance added in series with condenser C_1 is such as to limit the transient effect in the L_1C_1 circuit as can be determined from oscillograms of the action. Generally, this resistance will be about 10 per cent of the circuit impedance. The attack time in this

type of circuit is proportional to $\sqrt{L_1(C_2 + C_3)}$ and is very approximately equal to $1/2f_c$.

(*7.3*) *Measurement of Filtering.*—The term "Filtering" as used in reference to noise-reduction circuits described herein is defined as the difference in decibels between the amplitude of the fundamental signal in the modulating device and the noise amplitude of the bias component produced by the impressed signal. Since such a difference varies with the input and bias current the definition is said to apply to 10 db noise reduction and 6 db margin, and the filtering is measured at

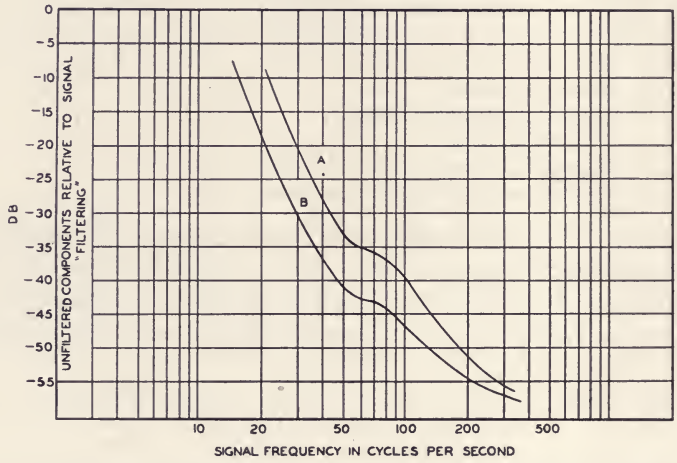


FIG. 11. Relation between unfiltered components in bias current and recorded signal as per definition of filtering. Condition of 10-db noise reduction, 6-db margin, half-cancellation of bias; (*A*) for push-pull timing (0.01 sec. attack, 0.04 sec. release); (*B*) for single-track timing (0.02 sec. attack, 0.04 sec. release).

that input condition where half-cancellation occurs. Starting at a frequency of 20 cycles, the output to the modulating device is first measured with both signal and bias currents present. Then the input signal is disconnected from the modulator and the noise components are measured. The difference between the two values (assuming a flat frequency characteristic) can then be computed. Other methods of measuring filtering are used which may be more convenient but the result should be the same. Fig. 11 shows typical filtering characteristics for (*A*) push-pull and (*B*) standard recording systems, respectively.

(8.0) A NEW NOISE-REDUCTION BIAS UNIT

An all-purpose noise-reduction bias unit, making use of the above-mentioned considerations, has recently been built. This will deliver sufficient bias to give closure on any Western Electric light-valve circuit and will also operate the Western Electric variable-area shutter. The timing is easily changed for standard or push pull track for either variable-area or variable-density records. Peak-type operation is em-

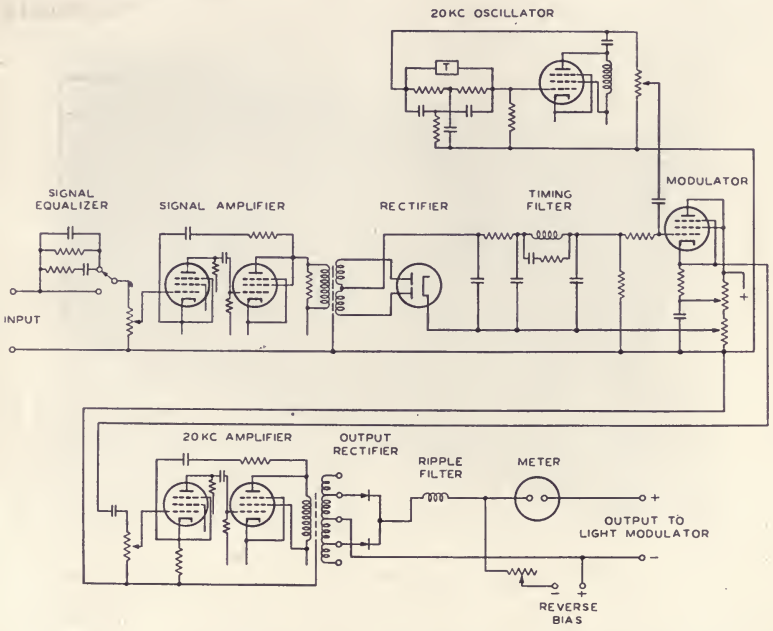


FIG. 12. Simplified schematic of *RA-1124* noise-reduction unit.

ployed. The output current is very stable in the presence of moderate supply-voltage variations. The operation is based on the carrier-type circuit, several examples of which have been described in previous literature.[9,10]

A simplified block diagram of the circuit used is shown in Fig. 12. It consists of an audio signal amplifier with a variable-gain control and equalizer, followed by a full-wave rectifier and filter which gives the desired timing and frequency characteristics to the rectified audio signal. This signal modulates the twenty kilocycles generated by the oscillator. The 20-kc amplifier amplifies the modulated signal which

is rectified, filtered, and supplied to the output as the noise-reduction bias current.

The input circuit is unbalanced, and has an impedance of about 5000 ohms so as to give less than one-half decibel bridging loss across a 500-ohm bus. An equalizer having a frequency characteristic similar to that of the light-valve can be connected in the circuit when used with light-valve recording systems to give the same frequency characteristic to the signal operating the noise-reduction unit as is effec-

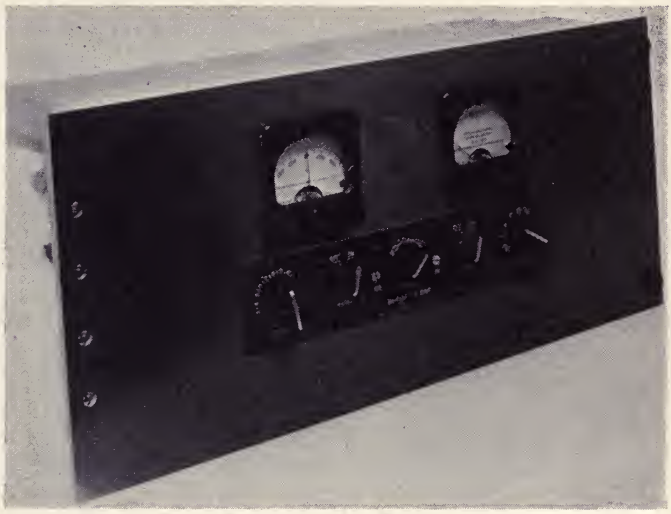


FIG. 13. *RA-1124* noise-reduction unit; front view.

tive in the modulation of the light-valve, or disconnected for modulators having a flat characteristic.

The signal amplifier uses a *WE 348-A* vacuum-tube for the gain stage followed by a *WE 349-A* power pentode for power. A 0.5-decibel-per-step potentiometer controls the gain of the audio signal amplifier, and is used in operation to set margin. Feedback is used over the two stages so that the gain is stable, and the output impedance is low. This amplifier overloads sharply and acts as a peak chopper at a few decibels above full cancellation of the bias output. This minimizes changes in operating times with audio signals greater than those necessary to cancel the bias to zero. The signal amplifier output is rectified by a *WE 351-A* full-wave diode power rec-

tifier, with a relatively low internal impedance. The low output impedance of the amplifier and the high impedance of the timing filter circuit contributes a close approach to peak operation.

A timing filter with an *R-C* section followed by an *M*-derived section with enough dissipation to eliminate undesirable transient effects is used. For normal light-valve recording an attack time of 20 milliseconds and a release time of 40–50 milliseconds are used. For push-pull variable-density an 8–10 millisecond attack and a 40–50 millisecond release are employed. These filters are mounted on "plug-in" bases, so filters with different characteristics can be used as desired.

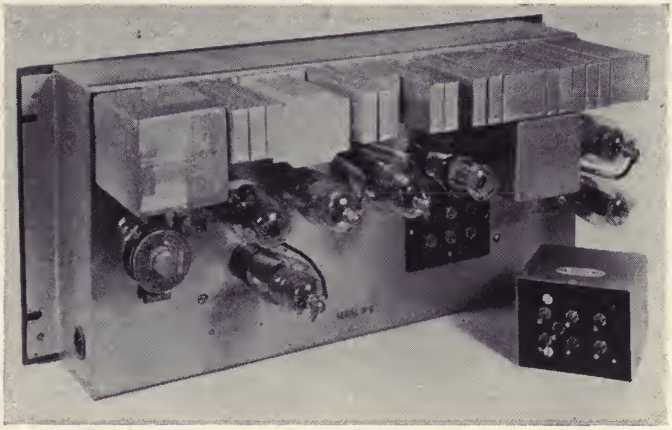


FIG. 14. *RA-1124* noise-reduction unit; rear view.

The output of the entire unit must be stable with supply-voltage variations. To accomplish this the output of the oscillator is regulated. This is achieved by using a stabilized *R-C* oscillator, the general principles of which are well known. The circuit actually used was one developed by the Bell Telephone Laboratories and has the advantage of simplicity and good stability. The Wien bridge determines the frequency of oscillation and the thermo-resistor stabilizes the output level.[11]

The modulator uses a *WE 348-A* vacuum-tube with negative grid-bias modulation, and the output is taken across the cathode resistor. The modulator output is stabilized relative to supply-voltage changes by obtaining grid bias from a voltage-divider across the high-voltage supply, and adjusting it to reduce the plate current just to zero with

no signals on the grid. At this adjustment the voltage on the plate is proportional to μe_g where μ is the amplification factor and e_g is the grid voltage. Any fluctuation in supply voltage shifts the grid bias an amount which just compensates for the changed plate voltage and the signal output remains substantially constant.

A threshold adjustment is given by returning the rectifier cathode to ground through an adjustable voltage-divider. This puts a bucking voltage in series with the timing-filter output so that audio signals below a desired level do not begin to cancel the bias. This enables the unit to be set up to operate with approximately constant margin as the bias varies in operation from maximum to minimum. Where "hush-hush" troubles are obtained this feature is sometimes used to advantage. However, for most work the threshold device is not used since it increases clipping.

The modulated 20-kc signal is amplified by a two-stage amplifier consisting of a *WE 348-A* gain stage, and a *WE 349-A* vacuum-tube power-output stage. A potentiometer controls the amplifier gain, and in operation is used to set the bias current. The output transformer has a one-ohm output winding for light-valve operation and a ten-ohm winding for area modulators. The desired winding can be connected to a full-wave copper-oxide rectifier and carrier filter, so that the envelope signal is supplied to the output as bias current. This unit will supply in excess of 0.8 ampere of bias current to a one-ohm load, or 0.25 ampere to a ten-ohm load. Provision is made to connect a d-c supply to the output circuit to furnish a reverse bias to the light-modulator. Photographs of the unit, which has been coded *RA-1124*, are shown in Figs. 13 and 14.

CONCLUSION

This paper has attempted to cover the salient points in the design and use of biased recording systems. The subject is a complex one and the authors are indebted to many individuals and especially to Mr. John Livadary for many helpful suggestions, original ideas, and information along this line.

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A PRECISION DIRECT-READING DENSITOMETER*

MONROE H. SWEET**

Summary.—*A photoelectric densitometer of the direct-reading type is described. A logarithmic amplifier circuit has been modified so as to give an accurately linear output with high stability. The instrument covers a density range of 0 to 3.0. Pertinent optical, electrical, and performance factors are discussed.*

INTRODUCTION

Historical Background of Objective Densitometers.—Ever since Hurter and Driffield's classic investigations of the characteristics of photographic emulsions, there has been a genuine need for accurate instruments to measure photographic densities. The state of development of optics and electricity during Hurter and Driffield's time necessitated visual instruments, and until relatively recently these have been developed almost to the complete exclusion of instruments using physical detectors. However, the advent of barrier-layer photocells and the development of vacuum phototubes paved the way for practical objective instruments. All densitometers of this class have several inherent advantages over subjective meters.

Present State of Densitometry.—When the present situation is surveyed, one finds that even now, visual densitometers overwhelmingly outnumber objective instruments. The chief reason for this seems to be that there is no commercially available photoelectric densitometer which is sufficiently simple, inexpensive, and satisfactory for general laboratory use. On the other hand, a number of photoelectric densitometers are described in the literature, but most of them suffer from one or more of the following objections:

(*1*) *Too complex:* Usually, the electrical circuit must be made complex in order to achieve high gain with reasonable stability. This necessitates several balance, calibration, and zero adjustments. Furthermore, such circuits are always a potential source of difficulty and require expert servicing in the event of circuit trouble.

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(*2*) *Too elaborate:* In an effort to fulfill preconceived (and sometimes unnecessary) requirements, some instruments have been made more elaborate than necessary. Often, the expedients used have seriously limited the light available to the phototube. This

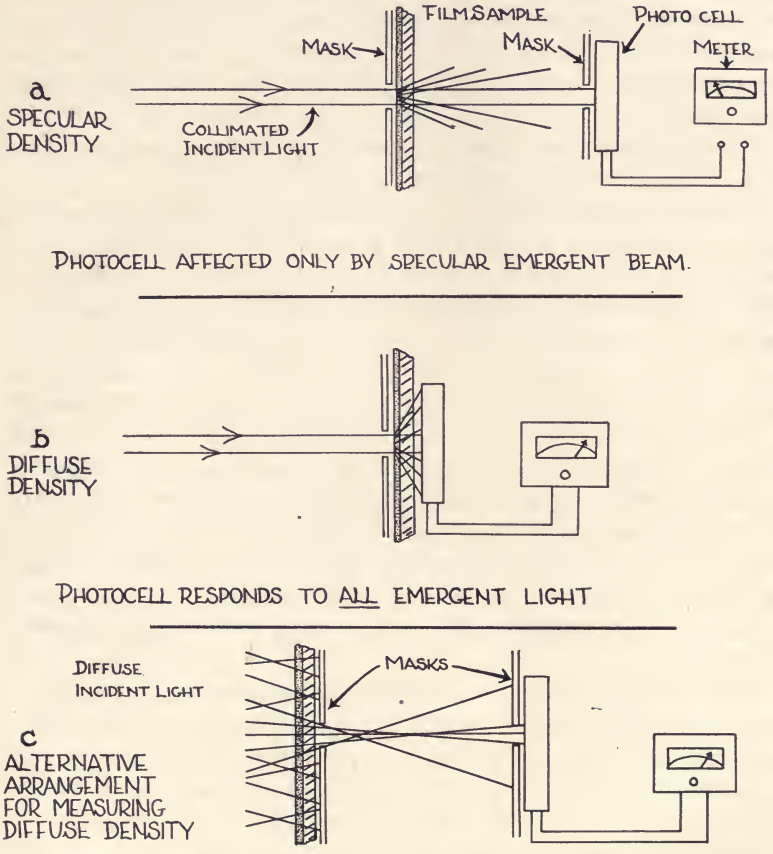

FIG. 1. Fundamental optical systems for measurement of density.

creates the need for amplifiers of extreme sensitivity with their attendant difficulties.

(*3*) *Insufficiently accurate:* Because of inherent instability, lack of suitable voltage regulation, or improper optical and electrical design, many densitometers are not capable of high accuracy.

(*4*) *Cramped scales:* Direct-reading instruments require a linear density scale to avoid excessive crowding at the high densities. Resort to a multi-range output indicator involves the inconvenience and confusion of range changing.

(*5*) *Too expensive:* The technical demands placed on an acceptable general purpose instrument are quite severe. For this reason, most densitometers have been either compromised in design or are prohibitively expensive, *i. e.*, they are not in the visual densitometer price class.

Other less important objections become apparent as the instruments are used under working conditions.

Measurement of Density.—Optical density was defined originally by Hurter and Driffield as the log $1/T$, where T is the transmission. Unfortunately, no specification as to the quality or direction of the incident light was mentioned nor was the sensitivity and positioning of the receiver. A film specimen that is illuminated by collimated light and examined specularly is said to be measured as to specular density. Such an arrangement is illustrated in Fig. 1(*a*). When the receiver is located so as to intercept all of the emergent beam (see Fig. 1*b*), diffuse density is measured. An alternative arrangement for measuring diffuse density is to illuminate the sample by diffuse incident light and examine it specularly (Fig. 1*c*).

The color quality of the light may influence the results and so may the color-sensitivity of the receiver. For example, a bluish tinted sample may have a high density to red light and a lower density to blue light.

If photographic layers were neutral, non-scattering absorbers, it would not matter what geometrical optical system was used nor would the spectral quality of the components make much difference. Actually, they are neither. This fact makes it imperative that the pertinent conditions be thoroughly understood before a satisfactory densitometer can be designed.

A moment's reflection will show that since the scattering power increases with an increased deposit of silver, the effect is to render specular densities higher than diffuse densities, and the density difference increases with the absolute density. The ratio of specular density $D_{\prime\prime}$ to diffuse density $D_{\#}$ at a particular density level is known as the Callier quotient. In an effort to insure fundamentally accurate density measurements, instruments have recently been designed whose geometrical optics exactly conform to the concept of diffuse

density. While such instruments are valuable in providing a readily accessible densitometer of the primary standard type, it will be shown later that conformity with theoretically ideal systems is quite unnecessary for densitometers used in routine work. After densitometers (using any practical optical system) have been calibrated as to diffuse density, they will give accurate readings on heterogeneous strips irrespective of grain size.

The problem of color correction is not so simple. It is legitimate to hold that the effective spectral sensitivity of the optical system should duplicate practice. However, "practice" may mean almost anything. In the case of the motion picture industry, in the duplicating process alone an ideal system should duplicate several different combinations:

(*1*) The combined spectral sensitivity of a mercury-vapor light-source or a tungsten light-source and dupe positive print material.

(*2*) The combined spectral sensitivity of a mercury source and dupe negative.

(*3*) The combined spectral sensitivity of a mercury source and release positive.

Different laboratories use different light-sources. Frayne[1] has met this problem by using a source-phototube-filter combination which approximates the spectral sensitivity of a tungsten-positive-film combination. He further suggests that other combinations be adopted where special systems are to be duplicated. In the various branches of photography, nearly every conceivable type of optical system and color-sensitivity occurs. The result is that the effective density of even a neutral-density sample may vary by as much as 0.70 at a density level of 2.5. The selection of a representative criterion by which all densitometers might be calibrated has been discussed in the past, and references are cited which will acquaint readers with a few of the recent papers.[2, 3, 4, 5] In March of this year, an "American Recommended Practice for Photographic Density" (ASA, Z-22.27) was announced as follows:

"The integrating sphere shall be used as a primary instrument for the determination of photographic density. Photographic densities determined by means of this primary instrument shall be used as secondary or reference standards by means of which densitometers of other types may be calibrated."

This specification is somewhat inadequate. The spectral attributes of density just discussed are not even mentioned in the report. It is

the writer's opinion that some form of contact printing density would be found suitable for standardization. However, once any workable standard has been agreed on, definite coefficients could be assigned which would correct the standard values to agree with various optical systems. Additional coefficients could be calculated to help compensate for color differences.

Requirements of the Densitometer.—In the light of the above considerations, the following elemental requirements were formulated to create a goal toward which to work.

(*1*) The instrument should be of the *objective type.* Visual densitometers impose severe eye fatigue if used continuously for long periods of time. In addition, they are limited in accuracy by the contrast sensitivity of the eye.

(*2*) *Accuracy* should be maintained to:

$$\pm 0.005 \text{ from } D = 0 \text{ to } D = 1.0$$
$$\pm 0.010 \text{ from } D = 1.0 \text{ to } D = 2.0$$
$$\pm 0.020 \text{ from } D = 2.0 \text{ to } D = 3.0$$

These figures are derived from a study of the accuracy required for standard sensitometric procedures.

(*3*) *Stability* should be commensurate with the specified accuracy.

(*4*) It should be *direct reading** and of the single-range type. This is to eliminate, so far as possible, the chance for mistakes on the part of the operator.

(*5*) *Good legibility* should be maintained over the entire range of the instrument. Density readings should be made easily without imposing eye-strain or physical discomfort.

(*6*) The densitometer should be *usable under ordinary room-lighting conditions.* This allows the instrument to be more conveniently located and permits working under more pleasant conditions.

(*7*) It should be mechanically *rugged* and *rapid* in operation. Existing visual instruments are mechanically rugged, so the new instrument should be capable of withstanding limited misuse. Speed of operation is considered desirable in order to accelerate the sensitometric work.

(*8*) It should read *diffuse density.* This aspect will be discussed separately.

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* Occasionally instruments of the balanced type are incorrectly referred to as direct-reading. True direct-reading instruments may be defined as those which indicate the density of the sample directly upon its insertion in the measuring beam without resort to further manual adjustments.

(*9*) The *cost* of the instrument as a whole should be competitive with that of visual instruments. Even if the other requirements were met, many prospective users would object to a cost appreciably higher than the prevailing cost of visual densitometers.

(*10*) Further miscellaneous factors such as reasonable size, appearance, and permanence of calibration had to be considered.

Having given careful attention to the factors outlined above, the model *11* densitometer was designed and constructed.

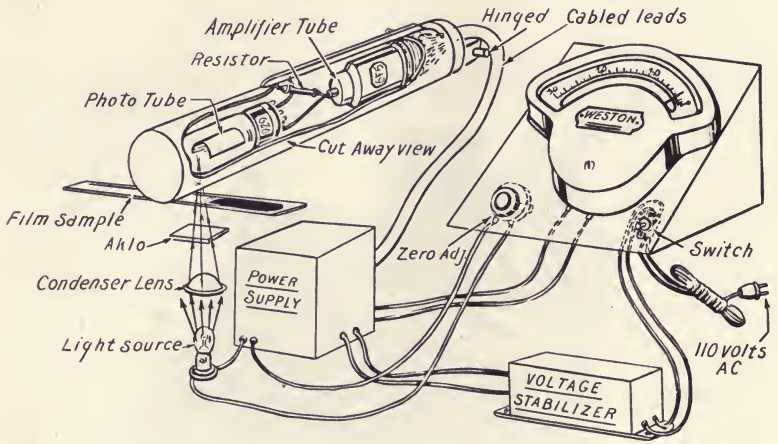

FIG. 2. Optical and mechanical pictorial diagram of model *11* direct-reading densitometer.

DESCRIPTION OF DENSITOMETER

Optical System.—The present optical system is very simple. The optics are represented in Fig. 2. Light radiating from a 15-cp concentrated-filament auto headlamp is focused by a single condenser on an aperture (not shown). A heat-absorbing filter is used to eliminate the infrared radiation. The sample to be measured is placed immediately over the aperture which is located in the base plate of the instrument (Fig. 3). After passing through the sample, the beam is absorbed by the phototube. The phototube, together with the amplifier tube, is mounted in a hinged cylinder (Fig. 10). Orientation of the sample with respect to the aperture is facilitated by raising the cylinder.

From our discussion of density measurement, the present optical system will be recognized as being neither diffuse nor specular. It can

most satisfactorily be described as a double-diffuse system since the sample is diffusely illuminated and the emergent light is diffusely received.

Referring to Fig. 4, *a* represents the path of the light-rays for a conventional optical arrangement. The density is, of course, measured in terms of the flux absorbed by the photosensitive element with the sample interposed, in comparison with the flux absorbed without the sample. In Fig. 4(*b*) diffuse illumination is represented. Obviously, nearly all the light has a longer optical path through the

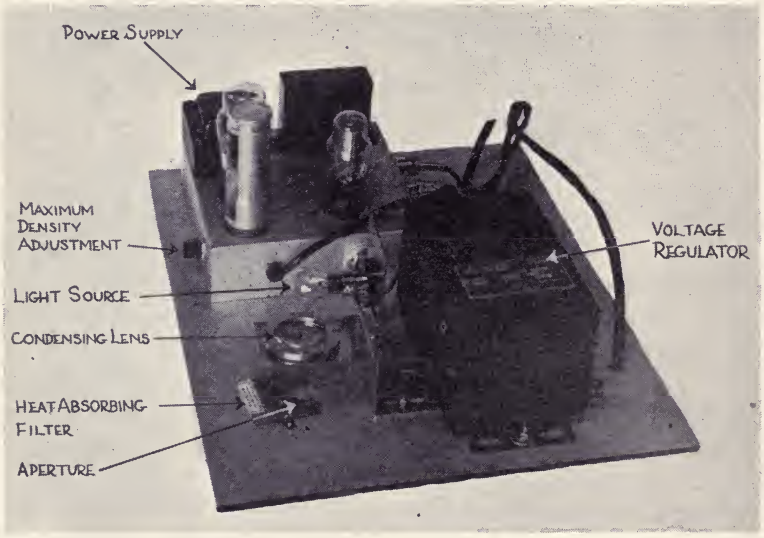

FIG. 3. View of underside of instrument showing location of components.

photographic layer in the second case than in the first, with the result that the apparent density of the sample is higher for diffuse illumination than for specular illumination. The magnitude of the difference may be calculated from Beer's law.

In an article on printing density,[12] Tuttle describes an apparatus whose optics are the equivalent of the components just described. This system gave higher density values than the simple diffuse type. However, Tuttle argued that the diffuseness of the source should not have influenced the results.

The model *11* densitometer was empirically calibrated, and the effect of the geometry of the illumination did not influence the accuracy of the values obtained.

The full intensity of the beam falls on the phototube when zero density is read. Otherwise, the intensity is modulated by the sample measured. The high sensitivity of the phototube-amplifier combination makes it possible to use a low-candlepower lamp (15 cp) operated

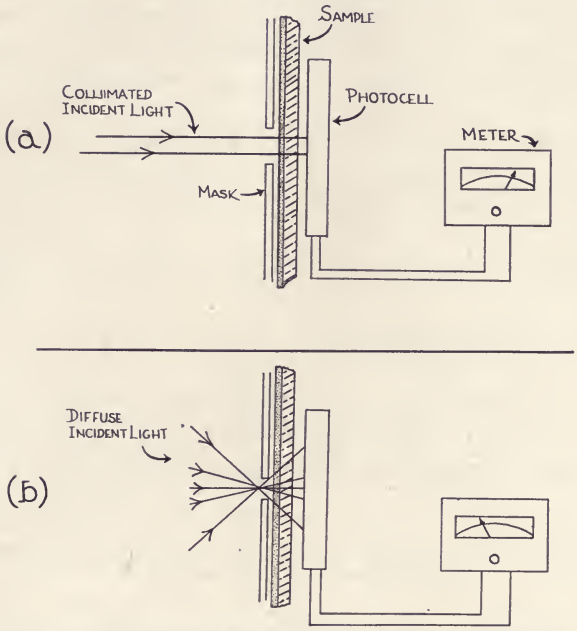

FIG. 4. Different optical systems for density measurement.

at considerably less than normal voltage (5.0 volts). The life expectancy of the lamp operated under these conditions is 40,000 hours.

Color Response.—The *929* phototube is the most sensitive vacuum phototube commercially available.* It is of the *Sb-Cs* coated type, and a plot of its spectral sensitivity is given in Fig. 5.** As mentioned earlier, Frayne[1] also used this tube and developed a source-phototube-filter combination which duplicates quite satisfactorily the color

* Rated at 45 μa/lumen for tungsten at 2870°K.

** Adjusted for tungsten at 2670°K and 2-mm Corning No. *596* filter.

attributes of an optical system wherein positive film is the light-sensitive medium. Until the problem of standardization of density measurements has been definitely settled, it seems justifiable simply to use whatever color combinations seem most pertinent for each particular case. In our meter, we are using the 15-cp source at a color-temperature of approximately 2670°K, the *929* phototube, and a 2-mm light-shade Aklo heat-absorbing filter.

Amplifier.—Most direct-reading photoelectric instruments have used electrical circuits with essentially linear amplifier response to phototube output. If unmodified, this gives a badly cramped density scale as shown in Fig. 6(*a*). The scale characteristics of the bal-

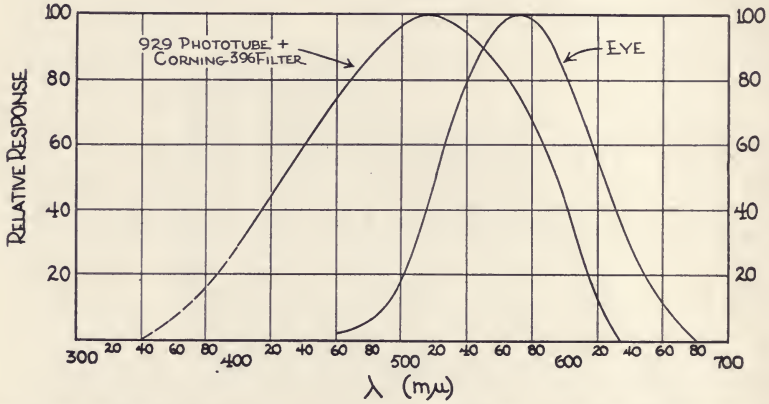

FIG. 5. Relative response of the light-source-filter-phototube combination and the eye, to tungsten at 2670°K.

anced-type densitometers depend on the particular optical scheme used and the design of the mechanical linkage. A combination can usually be found which will give a linear density scale.

The uniformity of the scale of barrier-layer photocell-microammeter systems can be improved by inserting a high series resistance in the circuit. However, this requires higher initial light intensities, thus decreasing the inherent stability of the circuit.

When using a photocell or phototube-amplifier combination whose output characteristics are linear with respect to intensity, it is feasible to use an output meter having cut pole-pieces. The Weston model *877* meter[6] is an example of the photocell type and the ERPI model *RA 1100*[7] an example of the phototube-amplifier type. While the improvement is quite helpful, it by no means gives a uniform den-

sity scale. Furthermore, cut pole-piece instruments are not evenly damped over their whole scale lengths. Consequently, meters of this type are under-damped and/or over-damped at some part of their scale.

These disadvantages may be avoided in a phototube-amplifier combination with a logarithmic response. Hardy[8] in 1929 described a logarithmic circuit for use in what is now called the GE Recording Spectrophotometer. Hardy's circuit is the prototype of the present design. Others[9, 10, 11] since Hardy's original disclosure have described

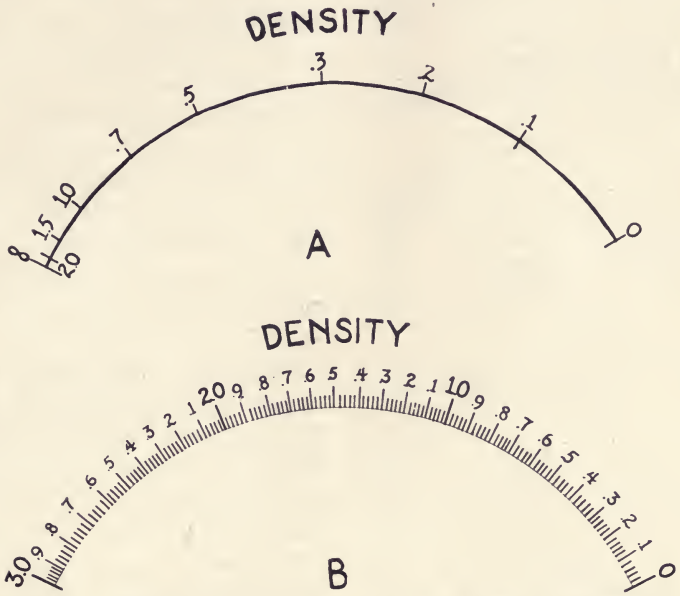

FIG. 6. Densitometer scales: (*A*) meter response proportional to incident intensity; (*B*) model *11* densitometer.

variations of the same fundamental circuit. In general, these logarithmic circuits have been somewhat unsuccessful. They were too unstable, especially when required to cover an intensity range of 1:1000 (this range of intensity corresponds to 0.0 to 3.0 density). Perfect linearity over this wide range was not claimed for any of these instruments.

The theory of the present amplifier may be explained by referring to Fig. 7. In this illustration, the phototube is connected directly to the grid of the *6F5* amplifier tube (a conventional triode). Light falling on the phototube will create a grid current and the potential

of the grid will tend to become positive. This gives rise to an increased plate current which is measured by the output meter. Roughly speaking, the following relationships apply:

(*1*) The light on the phototube is a linear (intensity) function of the transmission of the film sample.

(*2*) The phototube current is a linear function of the incident light.

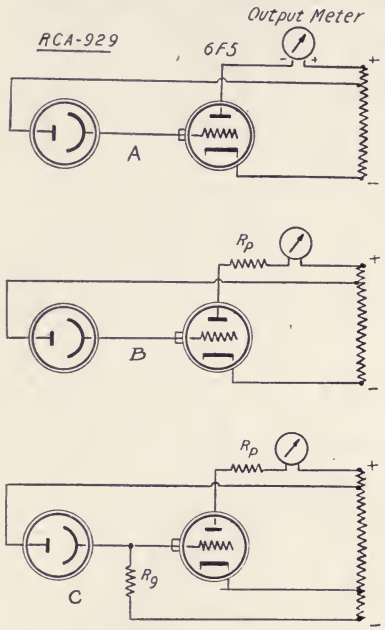

FIG. 7. Development of linear density *vs.* output circuit:
(*A*) Fundamental circuit.
(*B*) Plate resistor added.
(*C*) Plate resistor and grid resistor circuit added.

(*3*) The phototube current ≡ grid current.

(*4*) *The grid potential is a logarithmic function of the grid current.*

(*5*) The plate current is a linear function of the grid potential.

Density is defined as $D = \log 1/T$, and step No. 4 introduces the logarithmic relationship necessary to give a uniform density scale on the output meter. The electronic theory which explains step No. 4 has been outlined by Russell.[9]

Fig. 8(*A*) shows the relationship between sample density *vs.* plate current for the circuit of Fig. 7(*A*). Obviously it is not perfectly linear. In Fig. 7(*B*) a plate resistor has been added. This greatly improves the portion of the curve corresponding to the lower sample densities as shown in Fig. 8(*B*).

In Fig. 7(*C*) a very high-value grid bias resistor has been added. Its effect is to increase the cut-off value of the grid current of the tube as represented by the broken line of Fig. 8(*C*). By choosing the resistance value correctly, and by applying the proper bias voltage, a linear toe can be obtained.

The action of this grid circuit modification is quite interesting. The grid resistor serves to introduce a current which opposes the phototube-grid current. The magnitude of this bucking current is only of the order of 0.01 microampere. At a high density of, say, 3.0, the phototube current is about 0.02 μa and the bucking current has an

appreciable influence on the grid potential. At a density of 2.0, the phototube current is 0.20 and the effect of the bucking current is very small. For densities near zero, the photocurrent is 20 μa and the effects of the bucking current are undetectable. Hence it is clear that this grid circuit arrangement operates in such a way as to affect the density *vs.* plate current curve only at high-density values.

A schematic diagram of the circuit used in the model *11* densitometer is shown in Fig. 9. It will be noted that a bucking current is used in the plate circuit. This serves to shift the usable grid (and plate) current range to higher values giving better stability.

Fig. 10 shows the measuring head unassembled. The phototube, grid resistor, and amplifier tube are mounted, end to end, in the cylinder. This affords ideal electrical shielding. It is unnecessary to shield the various leads to the cylinder since there are no high impedances, exclusive of the grid resistor, which are in any way delicate. The measuring head can be detached from the base of the densitometer. It is then useful as an "exploring element" with which the intensity of light for small areas of a projected image may be measured. The logarithmic response of the circuit has a unique advantage in this application because it is the logarithm of the relative light-intensity in the plane of the paper that is important in projection printing.

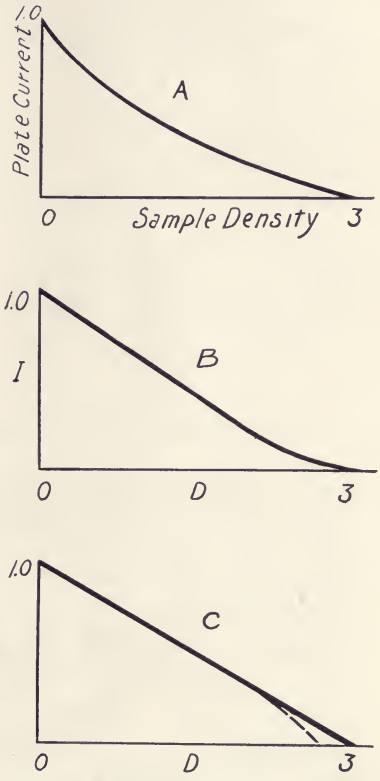

FIG. 8. Density *vs.* plate current for circuits of Fig. 5.

The extreme sensitivity of the instrument permits the measurement of very high densities. With the present low-cp source, densities up to 5.0 have been measured. A 50-cp headlamp operated at 7.5 volts should enable one to measure densities up to 6.0.

Suitably mounted, the measuring head could be used in reflection densitometry. The advantages of the logarithmic circuit would apply to such an instrument. The excellence of linearity to logarithmic

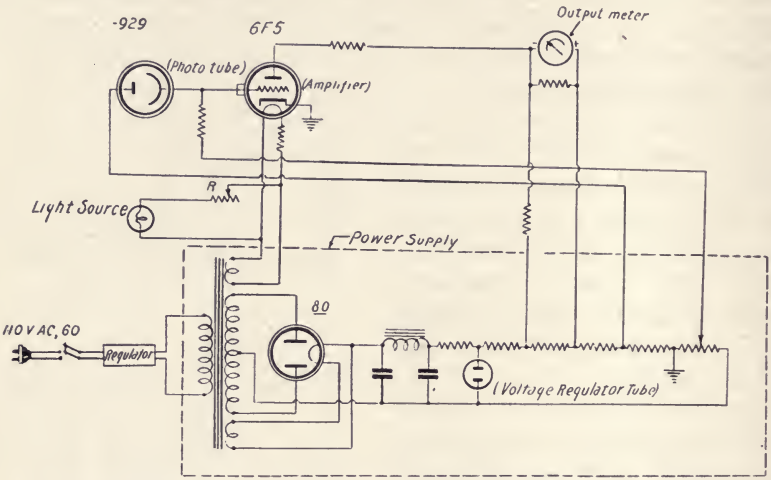

FIG. 9. Electrical circuit of model *11* direct-reading densitometer.

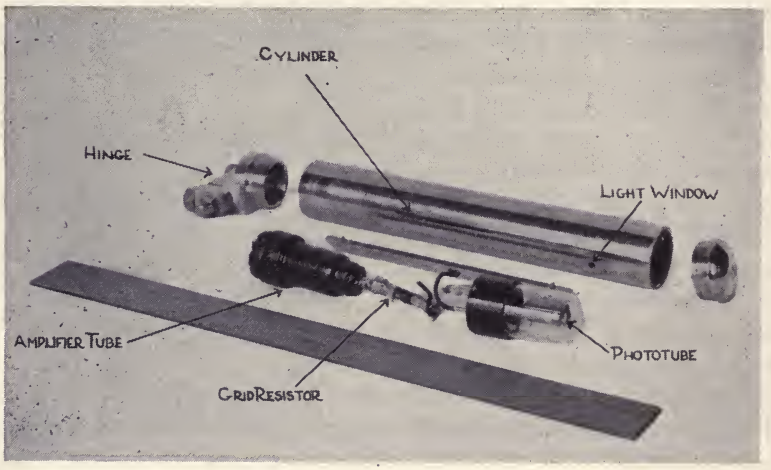

FIG. 10. Showing components of measuring head, unassembled.

changes in light-intensity, together with the high speed of response of the circuit and the relatively high (1.0 ma) output render the circuit adaptable for incorporation in the design of recording densi-

tometers. It should be especially valuable where continuous-tone sensitometer strips are to be automatically measured and recorded.

Calibration.—The hand-calibrated scale can, of course, be made to agree with any predetermined criterion. In the absence of widespread agreement on a standard type of density, the present densitometer was calibrated according to visual diffuse density. A carefully prepared neutral density wedge was read repeatedly by different workers using a visual diffuse instrument. These values were used as

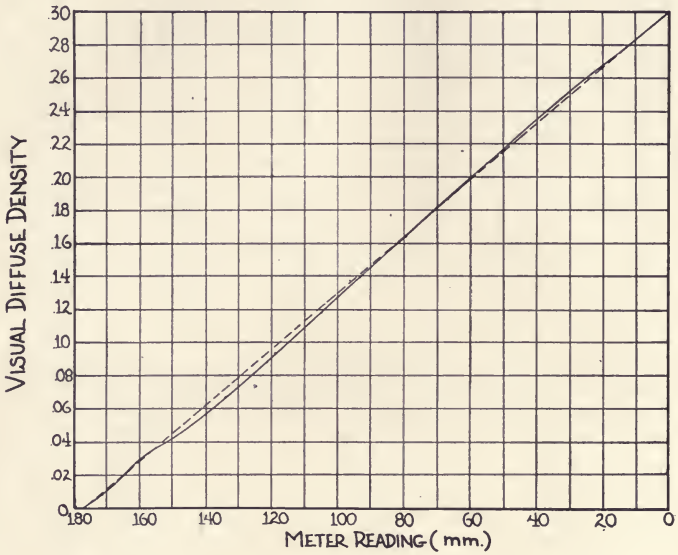

FIG. 11. Calibration of model *11* densitometer.

cardinal points and the scale of the instrument was graduated so as to agree with them.

The approximation to perfect linearity is illustrated by the facsimile scale ($^1/_2$ size) shown in Fig. 6(*B*). Fig. 11 is a plot of scale deflection in mm *vs.* visual diffuse density reading. Part of the apparent irregularities in the curve are known to be attributable to the unevenness of calibration of the visual densitometer which was used as the reference standard.

To determine the influence of grain size on the calibration, a fine-grain positive sensitometer strip and a coarse-grain high-speed negative were measured on both densitometers. Fig. 12 shows the results.

TABLE I

Effect of Grain Size on Density Measurements

Fine-Grain Positive Film			Coarse-Grain Negative Material		
Visual Diffuse Density	Photo-electric Density	Diff.	Visual Diffuse Density	Photo-electric Density	Diff.
0.05	0.04	−0.01	0.18	0.16	−0.02
0.09	0.07	−0.02	0.21	0.20	−0.01
0.13	0.13	0.0	0.27	0.25	−0.02
0.25	0.23	−0.02	0.35	0.34	−0.01
0.39	0.37	−0.02	0.46	0.42	−0.04
0.57	0.56	−0.01	0.57	0.54	−0.03
0.82	0.82	0.0	0.70	0.69	−0.01
1.10	1.12	+0.02	0.86	0.84	−0.02
1.40	1.42	+0.02	1.00	0.98	−0.02
1.71	1.73	+0.02	1.13	1.14	+0.01
2.02	2.02	0.0	1.27	1.29	+0.02
2.30	2.30	0.0	1.41	1.44	+0.03
2.54	2.54	0.0	1.56	1.56	0.0
			1.69	1.72	+0.03
			1.84	1.85	+0.01
			1.99	2.00	+0.01
			2.12	2.12	0.0
			2.25	2.26	+0.01
			2.40	2.40	0.0

TABLE II

Effect of Staining Developer (Sease 3) on Density Measurements

Visual Diffuse Density	Photoelectric Density	Difference
0.41	0.39	−0.02
0.43	0.40	−0.03
0.46	0.43	−0.03
0.53	0.49	−0.04
0.61	0.60	−0.01
0.70	0.71	+0.01
0.83	0.84	+0.01
0.97	0.98	+0.01
1.07	1.13	+0.06
1.22	1.29	+0.07
1.33	1.44	+0.11
1.51	1.61	+0.10
1.68	1.78	+0.10
1.85	1.93	+0.08
1.96	2.10	+0.14
2.12	2.24	+0.12
2.22	2.37	+0.15
2.28	2.45	+0.17
2.35	2.57	+0.22
2.43	2.64	+0.21
2.53	2.82	+0.29

Visual diffuse density is represented on the horizontal axis and photoelectric density minus visual diffuse density is scaled on the vertical axis. Table I gives the corresponding numerical values. In neither

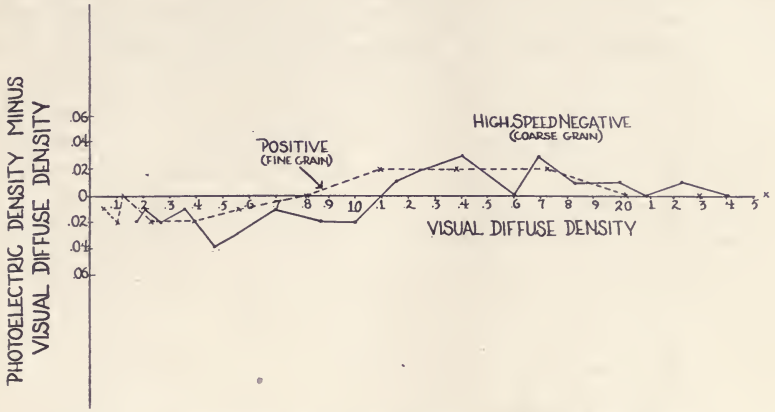

FIG. 12. Correction curves for samples of different grain sizes.

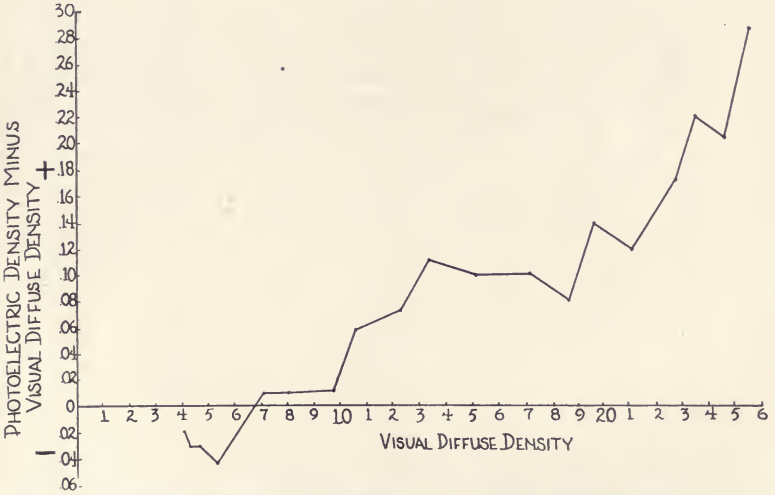

FIG. 13. Density difference (photoelectric *vs.* visual diffuse density) for a stained film.

case would it be possible in ordinary practice to discriminate between the photoelectric density and visual density curves for either of the two strips.

The situation is more unfavorable in the case of stained films, and reddish colored samples may show much higher photoelectric densities than visual values. A plot similar to Fig. 12 is shown in Fig. 13 for a strip developed in Sease *3* developer for 30 minutes. Table II gives the numerical values. The correction curve is serious enough in this case to give different gammas and film speed determinations.

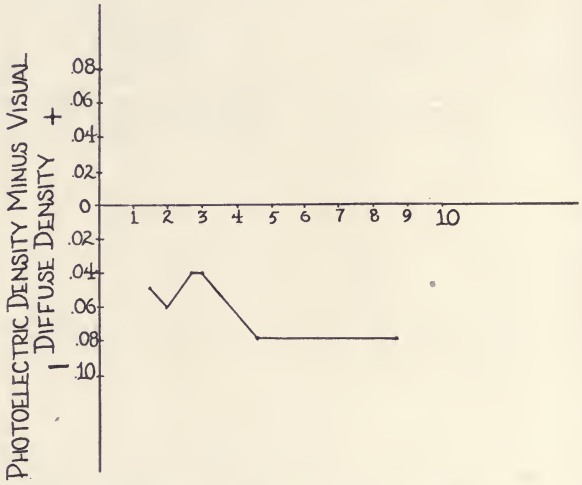

FIG. 14. Correction curve for a tinted base sample.

TABLE III

Effect of Tinted Base on Density Values

Visual Diffuse Density*	Photoelectric Density	Difference
0.16	0.11	−0.05
0.20	0.14	−0.06
0.26	0.22	−0.04
0.28	0.24	−0.04
0.44	0.36	−0.08
0.86	0.78	−0.08

Deposits on tinted bases are easier to deal with. For example, a blue base X-ray film gives good agreement with visual measurements when the base density is subtracted. A typical set of values is given in Table III, and the correction curve is shown in Fig. 14. Base-subtracted readings may be made directly once the light-inten-

* The visual diffuse densitometer used in this test was different from that used in all of the other tests. Its calibration is known to be somewhat different.

sity has been increased so as to give a zero reading with a section of the base alone in position.

The permanence of calibration of the instrument, both from day to day and in terms of months has been studied. Daily checks have been made since the instrument was first installed. Table IV is largely self-explanatory. It gives the readings made with the densitometer at a few typical daily and monthly intervals. At all densities up to 2.0, the variation in readings was negligible. At densities beyond 2.5 there was a noticeable tendency to give slightly higher readings with time. It is believed that this change is due to aging of the grid resistor, although it is possible that the amplifier tube characteristics may have changed. In any event, the shift is not serious, and can be corrected once every week or two by readjusting the grid bias potential.

TABLE IV

*Permanence of Calibration of Densitometer**

Calibration Wedge Step No.	Original Readings	17 Days Later	18 Days Later	19 Days	20 Days	25 Days
1	0.07	0.07	0.07	0.07	0.07	0.08
2	0.09	0.09	0.09	0.09	0.09	0.10
3	0.15	0.15	0.15	0.15	0.15	0.15
4	0.26	0.26	0.26	0.25	0.25	0.26
5	0.43	0.43	0.43	0.42	0.42	0.43
6	0.67	0.67	0.67	0.66	0.66	0.67
7	0.94	0.93	0.94	0.93	0.93	0.94
8	1.22	1.21	1.21	1.20	1.20	1.21
9	1.45	1.45	1.45	1.42	1.43	1.45
10	1.66	1.67	1.67	1.66	1.67	1.68
11	1.88	1.89	1.89	1.89	1.88	1.90
12	2.10	2.10	2.11	2.10	2.09	2.11
13	2.30	2.31	2.31	2.31	2.30	2.33
14	2.49	2.50	2.50	2.51	2.51	2.53
15	2.67	2.69	2.69	2.71	2.69	2.71
16	2.85	2.88	2.88	2.90	2.90	2.92

It is important to consider the effect of changing amplifier tubes. If their characteristics were not alike, the meter scale would have had to be recalibrated. To explore this possibility, a second *6F5* was selected at random and used to replace the original. Table V shows the

* The grid bias was left unadjusted during the period covering the above test. This was done to show the drift in high-density readings. Later, by decreasing the grid bias, the readings were made to agree with the original values.

TABLE V

*Effect of Replacement of Amplifier Tube**

Tube No. 1	Tube No. 2 Installed 43 Days Later	Difference
0.07	0.07	0.00
0.09	0.09	0.00
0.15	0.15	0.00
0.26	0.26	0.00
0.43	0.44	+0.01
0.67	0.68	+0.01
0.94	0.95	+0.01
1.22	1.22	0.00
1.45	1.45	0.00
1.66	1.67	+0.01
1.88	1.88	0.00
2.10	2.09	−0.01
2.30	2.28	−0.02
2.49	2.48	−0.01
2.67	2.66	−0.01
2.85	2.83	−0.02

* Note that the grid bias adjustment was imperfect as evidenced by the disagreement at high densities.

TABLE VI

Effect of Warm-Up Period on Meter Readings

	True Density*	After 1 Min	3 Min	5 Min	10 Min	15 Min
1	0.07	0.08	0.075	0.075	0.075	0.075
2	0.09	0.11	0.095	0.09	0.09	0.095
3	0.15	0.17	0.16	0.15	0.15	0.155
4	0.27	0.28	0.26	0.27	0.27	0.27
5	0.44	0.43	0.44	0.44	0.44	0.44
6	0.69	0.69	0.69	0.69	0.69	0.69
7	0.95	0.95	0.96	0.96	0.96	0.95
8	1.22	1.23	1.23	1.23	1.23	1.22
9	1.45	1.44	1.45	1.46	1.45	1.45
10	1.67	1.67	1.66	1.68	1.68	1.67
11	1.88	1.88	1.88	1.89	1.88	1.88
12	2.07	2.10	2.10	2.10	2.09	2.10
13	2.28	2.30	2.30	2.30	2.30	2.30
14	2.48	2.50	2.49	2.49	2.49	2.49
15	2.66	2.68	2.67	2.67	2.68	2.68
16	2.86	2.87	2.84	2.87	2.86	2.88

* Readings made 16 hours earlier after the instrument had been thoroughly warmed up.

comparison. It is obvious that a recalibration is unnecessary. A maximum density difference of 0.02 exists over a very limited region. Otherwise the agreement is within 0.01.

Performance.—Recalling the requirements set forth in the introduction, it will be realized that the first few, including accuracy, legibility, *etc.*, have been met. An inexpensive, low-power voltage-regulator stabilizes the power-supply voltages. The lamp voltage is taken from the filament winding of the secondary coil and is trimmed by a variable resistor. This gives stability quite consistent with the original specifications. Table VI demonstrates the warm-up period. One minute after turning the densitometer "on" (it having been left unoperated for 16 hours), a set of readings was taken; three

FIG. 15. Showing appearance of the model *11* densitometer in use.

minutes later, a second set; five minutes later, a third set, *etc.* Evidently the warm-up characteristics primarily affect only the higher density values. An idea of the size and appearance of the finished instrument may be gained from Fig. 15.

To show the freedom from zero drift, readings were made under conditions identical with those just described. The instrument was turned "on" and allowed to warm up for one minute. The zero adjustment was made. Every minute thereafter, for five minutes, the zero adjustment was repeated and a record made of the displacement of the pointer from zero. These values are shown in Table VII. After the instrument had been in operation for twenty minutes, a zero reading was made every 5 seconds for a total of one minute. At no time did the pointer vary by the width of the (knife-edge

type) pointer. This corresponds to a fluctuation of approximately two thousandths density.

TABLE VII

Effect of Warm-Up Period on Zero Drift

After 1 minute of operation zero was reset	
2 minutes of operation correction was	+0.005
3 minutes of operation correction was	+0.002
4 minutes of operation correction was	0.000
5 minutes of operation correction was	0.000
6 minutes of operation correction was	0.000

The influence of line voltage changes has been studied. After a thorough warm-up, the supply voltage was varied in steps of 5 volts, from 95 to 125 volts, and the zero readings were recorded. The data for this test are compiled in Table VIII. Apparently a variable supply voltage is not a problem.

TABLE VIII

Influence of Line Voltage

Line Voltage	Zero Reading
95	+0.005
100	0.000
105 (normal)	0.000
110	−0.002
115	−0.010
120	−0.010
125	−0.010

Ease of reading on the part of the operator has been insured by using an output meter of excellent legibility. The scale length is 178 millimeters, about 7 inches. (The ordinary 3-inch panel instrument has a scale length of only 50 mm.) This long scale is essential to an accurate single-rate instrument. It allows the divisions to be spaced $1^1/_5$ mm apart, each division corresponding to 0.02 density. In searching for practical objections to the densitometer, operators have been asked whether or not the legibility was satisfactory. All agreed that a still longer scale would not further improve the ease of reading.

The output meter has a sensitivity of 1.0 ma. It is not at all sluggish, having a speed of response of about $^1/_5$ second, and is uniformly damped over its entire range. Its steel case minimizes the effects

of external magnetic and electrostatic fields besides protecting it from mechanical damage.

In our laboratories, trained operators require approximately 45 minutes to read and record the densities of ten Type II*b* sensitometer strips using conventional visual instruments. With the model *11* densitometer, this time is reduced to only 20 minutes.

All the component parts of the instrument are rigidly mounted on the $^1/_4$-inch thick base-plate. The plate is flush-mounted in a small table built for the purpose. This makes servicing very convenient, for the whole instrument may be removed as a unit to a work-table and the various parts are then readily accessible.

TABLE IX

Results Obtained by Different Observers Using the Model 11 Densitometer

Step No.	Observer No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
1	0.06	0.05	0.05	0.05	0.06	0.05
2	0.085	0.08	0.08	0.09	0.085	0.08
3	0.14	0.14	0.13	0.15	0.14	0.12
4	0.28	0.28	0.28	0.29	0.29	0.28
5	0.49	0.48	0.48	0.49	0.49	0.48
6	0.79	0.79	0.79	0.79	0.785	0.79
7	1.13	1.13	1.12	1.13	1.13	1.12
8	1.43	1.43	1.43	1.43	1.44	1.43
9	1.68	1.67	1.68	1.68	1.69	1.68
10	1.90	1.89	1.90	1.90	1.91	1.90
11	2.09	2.08	2.09	2.10	2.10	2.09
12	2.25	2.25	2.26	2.26	2.26	2.25
13	2.39	2.39	2.39	2.40	2.40	2.39
14	2.52	2.51	2.51	2.52	2.53	2.52
15	2.65	2.66	2.66	2.67	2.67	2.68
16	2.79	2.79	2.78	2.80	2.81	2.80

As a final test, six individuals were asked to read the same sensitometer strip on the model *11* densitometer. Some were previously unfamiliar with the instrument. The results are compiled in Table IX. Of the 96 values tabulated, only two lie outside the specified accuracy limits (readings 4 and 6 of step No. *3*). Even in the case of these readings, the errors may be partly attributed to unevenness in the density of the sample. The measuring aperture is about 3 mm in diameter and shifting the position of ordinary samples within a given step will produce density variations up to 0.03 (due in part to the Eberhard effect). Furthermore, the presence of dust particles on the

sample will sometimes increase the apparent density. Nevertheless, the accompanying data are considered sufficiently reliable to demonstrate the performance of the instrument as it is used in actual practice.

CONCLUSIONS

A simple direct-reading densitometer has been built which facilitates the measurement of transmission densities. The electronic arrangement was so designed as to give a strictly uniform density scale over the entire range covered (0.0 to 3.0). It has been demonstrated that for the simple optical system used, the accuracy of the instrument was unaffected by the grain size of the materials measured.

Reproducibility, stability, drift, and other factors were shown to have a negligible influence on the accuracy of the instrument. In general, the densitometer was shown to fulfill the requirements agreed on before its construction was undertaken.

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DISCUSSION

DR. FRAYNE: The author stated in his paper that one of the reasons for undertaking the development of this densitometer by his organization was the fact that there was no commercial instrument of this type available. I wish to point out that the precision integrating sphere densitometer developed by Electrical Research Products, Inc., and described in the August, 1940, issue of the JOURNAL has been made commercially available during the year 1941 and has had wide adoption in the motion picture laboratories and studios in Hollywood and elsewhere. To indicate the almost universal adoption of this instrument at this time, I would like to show its disposition in the various organizations.

	Number of Instruments
20th Century-Fox West Coast Lab.	3
M. G. M. Laboratory	3
Paramount West Coast Laboratory	2
Paramount East Coast Laboratory	2
Consolidated West Coast Laboratory	1
De Luxe Laboratory	1
Pathe West Coast Laboratory	1
Technicolor	1
Williams Laboratory	1
Triplett & Barton X-Ray Laboratory	1
DuPont Film Manufacturing Co.	1
Eastman Kodak (Rochester)	1

These instruments are not being used primarily as primary standards in these various institutions, but are in active use in daily control operations. It is obvious, from the number and the distribution of the instruments that have been made available to the motion picture industry within one year, that this instrument most certainly may be regarded as being commercially available.

The operation of the instrument is extremely simple and measurements can be made rapidly and accurately by relatively unskilled observers. The multi-range feature permits an extended scale for each density range and adds materially to the ease of making observations.

MR. SWEET: I did not intend to disparage the merits of the ERPI densitometer which I sincerely believe to be an excellent piece of equipment. Nevertheless, this instrument does not meet the essential requirements set forth in the introduction of our paper, and, furthermore, it suffers from some of the objections which apply to many photoelectric instruments.

(*A*) The ERPI densitometer is certainly not simple, and complexity was given as a criticism of most objective instruments. The electrical circuit consists of a multi-stage amplifier with inverse feedback. Its optical system is relatively complex, using a chopping disk, diffusing block, sphere, *etc.* These complications are always a potential source of trouble. Furthermore, the amplifier requires several balance and zero adjustments for regular operation.

(*B*) The cost of the ERPI sphere instrument is considered prohibitive by many laboratories, at least for application involving routine work. Its cost is in excess of $1000, whereas the present instrument costs a fraction of this figure.

(*C*) While the ERPI densitometer may be considered a direct-reading instrument it is of the multi-range type, and this feature was explained as being undesirable. The present instrument is of the single-range type, and still affords excellent legibility over the entire density range covered.

As a standard instrument, Dr. Frayne's densitometer may establish itself in the photographic industry but the writer feels he has adequately demonstrated that a much simpler instrument of the type described will suffice for routine work.

MR. CARLSON: What is the influence of line voltage changes on the accuracy of the meter readings?

MR. SWEET: The effect is very small. Table VII shows the magnitude of the shift in the zero reading for a line-voltage variation of 95 to 125 volts in increments of 5 volts. A Sola 30-watt magnetic-type regulator is used in this instrument because in the immediate application the voltage fluctuations were unusually severe. The regulator is obviously very effective in preventing any sizable zero drift. In applications where normal fluctuations exist it might be feasible to dispense with the regulator.

AN ANALYSIS OF THE APPLICATION OF FLUORESCENT LAMPS TO MOTION PICTURE PHOTOGRAPHY*

REINHARDT ROSENBERG**

Summary.—*A brief discussion on photographically important characteristics of fluorescent lamps is followed by a thorough mathematical analysis of the constancy of light produced by fluorescent lamps. The conclusion is reached that, during exposure times ordinarily encountered in motion picture photography, the constancy of light from fluorescent lamps, if these are properly applied, far exceeds minimum requirements and that, even for extremely short exposure times, this constancy is well within accepted limits.*

The readiness with which still photographers have accepted fluorescent lamps as illuminants invites an investigation of their use in commercial motion picture photography. The high luminous efficiency and the lack of heat and glare of these lamps would seem to make them highly desirable as light-sources, as their use would effect considerable savings in operating expense and would, also, greatly increase the comfort of technicians and actors. However, it must be left to writers more competent on these subjects to weigh the savings in operation against the initial investment, and to determine whether the low surface brightness of fluorescent lamps is compatible with the high levels of illumination prevalent in modern motion picture studios. It is intended to limit this article to a careful analysis of the physical possibility of using these lamps for motion picture photography, and to the photographic and technical aspects involved.

Only the 3500° white, the blue, and the daylight fluorescent lamps can be considered for general illumination. The others are too distinctly "colored" to be of use for photographic purposes, and the light of some is filtered which reduces their luminous efficiency. As has been shown elsewhere[1] the three lamps mentioned above differ in the following characteristics: (*1*) luminous efficiency, *i. e.*, production of lumens per watt; (*2*) photographic efficiency, *i. e.*, the

* Received October 18, 1941.

** Department of Anatomy, University of Pittsburgh School of Medicine, Pittsburgh, Penna.

shortest exposure time required to produce a given density under standard conditions and at a specified gamma; (*3*) energy distribution over the photographically effective range of the spectrum; (*4*) flicker, or time-energy characteristic; and (*5*) shape of the *D*-log *E* curve of an emulsion exposed to the various lamps.

Each lamp, compared with either of the other two, is superior in some characteristics and inferior in others. The white lamp possesses the highest luminous efficiency and the least flicker. However, its photographic efficiency is less than that of either the blue or the daylight lamps. The flicker of this lamp is only slightly less than that of the daylight lamp. Furthermore, the *D*-log *E* curve of a pan-

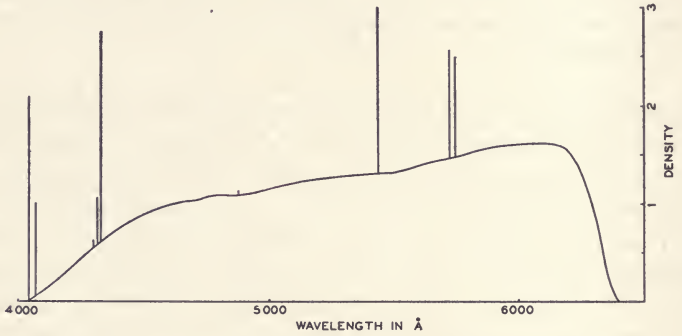

FIG. 1. Spectrogram of the daylight fluorescent lamp, photographed on a Wratten tricolor panchromatic plate.

chromatic emulsion, when exposed to the white lamp, has a shorter straight-line portion than is the case when exposed to the blue or the daylight lamp. It is, therefore, not a good choice.

Of the three lamps, the blue lamp has the highest photographic efficiency, and exposure of photographic emulsions to it produces a straighter *D*-log *E* curve than either the daylight or the white lamp. It can not, however, be considered a good choice as it has by far the worst flicker and the worst spectral characteristics. Its energy in the red portion of the spectrum is negligible so that it produces on panchromatic materials results similar to those of an orthochromatic emulsion. It would therefore require radical and undesirable changes in make-up technic.

By the process of elimination the daylight fluorescent lamp must be considered the proper choice. All its characteristics, when con-

sidered separately, are inferior to either the 3500° white or the blue lamp, but taken as a group they indicate that this lamp is the most desirable of the three. The spectrogram of the daylight lamp, photographed on a type *B* panchromatic emulsion, is shown in Fig. 1. This illustration is similar to the well known wedge spectrograms and its interpretation is subject to the same limitations. Fig. 2 shows a typical series of *D*-log *E* curves and a time-gamma curve, also obtained from a type *B* panchromatic emulsion, and Fig. 3, curve *A*, illustrates the flicker or time-energy characteristic of the daylight fluorescent lamp. Curve *A* in Fig. 3 was obtained by photo-

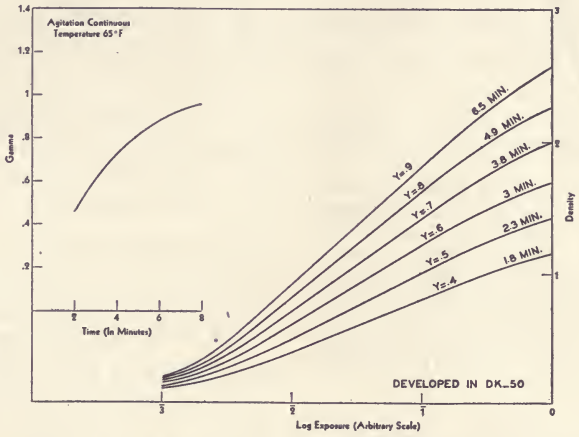

FIG. 2. *D*-log *E* curves and time-gamma curve of Eastman portrait panchromatic film, exposed to the daylight fluorescent lamp.

graphing the screen of a cathode-ray oscilloscope which was tracing the current induced in a photoelectric cell when exposed to a daylight fluorescent lamp, operated on 60-cycle, 110-volt, alternating current. The most serious objection to the use of this or any other fluorescent lamp for illumination in motion picture photography is the fluctuating character of the light it produces. In order to explain this flicker a knowledge of the following facts is helpful:

Fluorescent lamps are glass tubes whose walls are covered on the inside with fluorescing substances. A low-pressure mercury arc within the tube produces ultraviolet light which, in turn, excites the fluorescence. As in all gas-discharge lamps, little energy is stored in the fluorescent lamp, and, twice during each cycle, when the cur-

rent goes through zero, the production of ultraviolet light ceases. The lamp does not become completely dark, however, since fluorescence persists to some extent until the next impulse occurs. Although the flicker can be eliminated by operating the lamp on direct current, this is not advised by the manufacturer because the lamp does not operate as satisfactorily on direct as on alternating current, and because its high luminous efficiency is largely sacrificed when it is operated on direct current. The effect of the flicker can, however, be overcome if three banks of equal numbers of fluorescent lamps are operated on each of the three phases of three-phase alternating current.

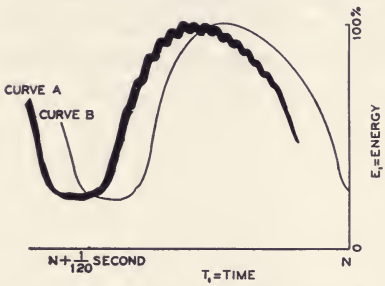

FIG. 3. Curve A shows the time-energy characteristic of a daylight fluorescent lamp, operated on 60-cycle, 110-volt alternating current. Curve B is the graphical presentation of the function of curve A, harmonically analyzed to close congruence. For the sake of pictorial clarity curve B is shifted horizontally to the right.

The constancy of light so obtained will now be analyzed. In this analysis the ripple on top of the wave, apparently caused by a secondary emission, will be disregarded since its magnitude is negligible compared with the total light output and its frequency is too high to be of practical significance. Curve A, Fig. 3, was harmonically analyzed by making use of Fourier's series of the well known form

$$f(x) = A_0 + A_1 \sin \frac{2\pi x}{a} + A_2 \sin \left(2 \cdot \frac{2\pi x}{a}\right) + \ldots A_n \sin \left(n \cdot \frac{2\pi x}{a}\right) +$$

$$B_1 \cos \frac{2\pi x}{a} + B_2 \cos \left(2 \cdot \frac{2\pi x}{a}\right) + \ldots B_n \cos \left(n \cdot \frac{2\pi x}{a}\right)$$

where

$$A_0 = \frac{1}{a}\int_0^a y dx$$

$$A_n = \frac{2}{a}\int_0^a y \sin \left(n \cdot \frac{2\pi x}{a}\right) dx$$

$$B_n = \frac{2}{a}\int_0^a y \cos \left(n \cdot \frac{2\pi x}{a}\right) dx$$

The analysis was carried to the fifth harmonic, resulting in the function

$$E_1 = f(t_1) = 691.6 + 12 \sin (0.1744t_1) + 2.45 \sin (0.3495t_1) + 0.34 \sin (0.523t_1) + 0.72 \sin (0.6975t_1) + 0.25 \sin (0.872t_1) - 3.77 \cos (0.1744t_1) + 1.43 \cos (0.3495t_1) + 0.15 \cos (0.6975t_1) + 0.45 \cos (0.872t_1)$$

where

E_1 = instantaneous luminous energy
t_1 may assume any values between 0 and $^1/_{120}$ second
$^1/_{120}$ second = 2π = 36 cm in the original curve.

The curve of this function is shown in curve B, Fig. 3 which is sufficiently congruent with curve A for all practical considerations. The position of $E_1 = 0$ was calculated from the manufacturer's data concerning the variation from the mean of the instantaneous lumen output of this lamp.[2]

The instantaneous lumen output of three lamps, operated out of phase on three-phase alternating current is given by the function

$$E_3 = f(t) = f(t_1) + f(t_1 + {}^1/_{360}) + f(t_1 + {}^1/_{180})$$

and is shown graphically in $f(t)$, Fig. 4.

Since the function $E_3 = f(t)$ is not a constant it is apparent that the amounts of light produced during a given time-interval will vary with the position of this interval in relation to the period of the function and that they will vary less as the interval becomes longer. If, during the exposure-time per frame, these amounts should vary by more than 10 per cent, a standard suggested elsewhere in the literature,[3] fluorescent lamps would have to be rejected as illuminants for motion picture photography.

The maximum and minimum amounts of light produced during $^1/_{48}$ second will now be calculated. This interval was chosen since it is obtained with the common camera speed of 24 frames per second and a shutter opening of 180 degrees. All possible amounts of light produced during $^1/_{48}$ second are expressed by the integral

$$\int_n^{n+1/48} E_3 dt = \Phi(n) = \int_n^{n+1/48} [f(t)dt = \int_n^{n+1/48} [f(t_1) + f(t_1 + {}^1/_{360}) + f(t_1 + {}^1/_{180})]\, dt$$

where n may assume any values between 0 and $^1/_{360}$ second. Twelve integrations of this function were carried out, assuming for n successive values of $\frac{1}{12 \times 360}, \frac{1}{11 \times 360}, \frac{1}{10 \times 360}, \ldots \frac{1}{360}$. These inte-

grations revealed that the luminous output of three daylight fluorescent lamps, operated under conditions indicated above, and taken during random intervals of $^1/_{48}$ second, does not vary by more than 0.1 per cent, since the calculations, which were carried to the third significant number, showed no variations at all.

It is easily understood that amounts of light emitted during a given interval will show greater variations as the interval becomes shorter, reaching the greatest possible variation at infinitesimally short intervals.

FIG. 4. Curves $f(t_1)$, $f(t_1 + 1/360)$, and $f(t_1 + 1/180)$ show, in proper time relationship to each other, the time-energy curves of three daylight fluorescent lamps, operated on three-phase current. Curve $f(t)$ illustrates the time-energy curve of the light produced by the combination of the three lamps, *i. e.*, their algebraic sum.

Shortened exposure times occur in three instances: (*1*) in fades and lap dissolves made by reducing the shutter opening; (*2*) in slow-motion photography; and (*3*) in full exposures with reduced shutter opening. Although it is the most frequent, the fade is perhaps the least important of these since it lasts only a short time, since exposure times per frame vary continuously during the operation, and since a poor fade will hardly detract from the merits of an otherwise good motion picture. Slow-motion photography is usually applied only in outdoor sport events or, when light conditions are not under the control of the motion picture operator, but it is worthy of consideration since it might find application in studio trick photography. The most important instance of shortened exposure time is, undoubtedly, full exposure with reduced shutter opening since this is an important device to improve the definition of an image that moves with great rapidity across the image plane.

For these instances of reduced exposure time it might be interesting either to find the shortest exposure during which a predetermined constancy of illumination can be maintained or, assuming an infinitesimally short exposure, to calculate the maximum and

minimum values for E_3. This latter was carried out by letting the first derivative of the function $E_3 = f(t)$ equal zero:

$$dE_3/dt = f'(t) = 0$$

and, thereby, determining the values of t at which the maximum and minimum occur. The values for t, so obtained, were then substituted in the equation $E_3 = f(t)$ and the magnitudes of the maximum and the minimum were determined. It was found that, during infinitesimally short exposures, the least amount of light is 88.9 per cent of the maximum or, in other words, the variation from the mean is only about 5 per cent. It is reasonable to deduce that, for the shortest exposure times practicable, the previously accepted standard of a 10 per cent variation is easily maintained.

In conclusion, it can be stated that daylight fluorescent lamps, if properly applied, can be successfully used as illuminants in motion picture photography, *i. e.*, they can produce illumination of great constancy, and their light is photographically satisfactory. In addition, their use may result in considerable economies.

Grateful acknowledgment is made to the General Electric Company for making available the lamps and fixture used in this work.

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IODIDE ANALYSIS IN AN MQ DEVELOPER*

R. M. EVANS, W. T. HANSON, JR., AND P. K. GLASOE**

Summary.—*A method is described for the analysis of iodide in a developer involving precipitation of the halide with silver nitrate and oxidation of the iodide while it is in the form of solid silver iodide to iodate with chlorine water. The iodate is then determined polarographically. Quantities of iodide from 2.5 to 10 milligrams of potassium iodide were analyzed with an accuracy of 2–4 per cent. Thiocyanate in the developer interferes but it can be removed by boiling with strong sulfuric acid before precipitation.*

Using this method of analysis it was shown that an equilibrium amount of iodide is obtained in a developer. Curves are given showing the attainment of equilibrium for development of Eastman panchromatic negative motion picture film, in Kodak D-76, and in Kodak D-16 developers, and Eastman positive motion picture film in Kodak D-16. The equilibrium value depends on the emulsion, the developer, the developed density, and perhaps other variables which will be investigated more thoroughly.

During the last several years, an attempt has been made to apply chemical analysis to the complete control of photographic developers. Evans and Hanson,[1] Baumbach,[2] and Atkinson and Shaner[3] have published analytical methods for most of the important constituents of developers.

One result of a complete knowledge of the chemical composition of an aged developer would be the ability to match the developing properties of a used developer by means of a freshly mixed solution. Recent attempts to accomplish this by using only the analyses already published have not given entirely satisfactory results. There are some indications that the amount of iodide which accumulates in a used developer plays a significant role in the developing properties and must be added to the synthesized formula. Because of this need, the following method for determining iodide in a used developer solution has been worked out.

Rylich[4] first demonstrated that iodate ion could be reduced at the dropping mercury electrode. This reaction is the basis of the test.

* Received May 15, 1941; communication No. 808 from the Kodak Research Laboratories.

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

The dropping mercury electrode[5] is composed of mercury dropping from a capillary tube immersed in a solution. The mercury column within the capillary is connected externally to a pool of mercury at the bottom of the container (or to a calomel electrode which is immersed in the solution) by means of a variable source of potential and a galvanometer. When a potential difference is applied, a current flows. This current fluctuates, reaching a maximum just before each drop falls, then decreasing suddenly when the drop falls and slowly rising to the maximum again. As this potential is increased, the maximum current increases slowly. However, if in the solution some material is present which is reducible at the dropping mercury electrode, it will begin to be reduced at a potential characteristic of this material and a large increase in the current will occur. As the potential is increased further, the current-voltage curve flattens off. This gives rise to a "wave," the height of which is proportional to the amount of the material present. This height can be used as a method for determining the amount of an electroreducible material present.

In order to determine iodide in a developer, the iodide, which is not electroreducible, must be oxidized to iodate, and interfering substances which are reducible at or near the reducing potential of iodate must be removed. Separating the iodide by precipitation was avoided at first in the hope of keeping the procedure as simple as possible. Several attempts were made to oxidize iodide to iodate directly in a developer solution. To eliminate the necessity for using excessive amounts of the oxidizing agents, the sulfite was removed by acidification and by passing steam through the solution, and the developer was removed by extraction with ethyl acetate. Nevertheless, a large amount of some oxidation products which gave high currents was always formed and interfered with the results. Several different oxidizing agents, both solid and dissolved, were investigated. Attempts were also made to remove the undesirable oxidation products by extraction and adsorption but without success.

The next attempts were made using weaker oxidizing agents that would only oxidize the iodide to iodine which could be extracted with carbon tetrachloride and later oxidized to iodate. Using this procedure, only a small fraction of the iodide present could be accounted for, and it was concluded that the iodine formed by oxidizing the iodide reacted with the oxidation product of the developer so was not available for extraction by the carbon tetrachloride.

After these failures it was concluded that the iodide would have to

be separated from the developer solution by precipitation with silver. In this way all of the halide present in the developer, including the iodide, could be separated from the interfering substances in the developer by decantation and washing. At first, it was considered necessary to put the precipitated silver halide into solution before oxidizing the iodide to iodate. This again produced interfering substances and led to a rather involved method for removing them.

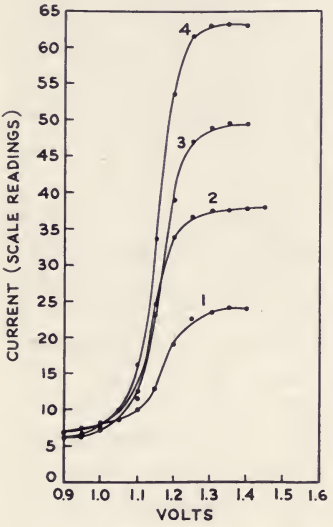

FIG. 1. Dropping mercury electrode "waves" for iodate; amount of iodate equivalent to
(*Curve 1*) $2^1/_2$ mg/l of KI
(*Curve 2*) 5 mg/l of KI
(*Curve 3*) $7^1/_2$ mg/l of KI
(*Curve 4*) 10 mg/l of KI

It was finally found that the procedure could be shortened considerably by oxidizing the iodide in the precipitate itself rather than after redissolving. This eliminated all of the interfering substances and yielded curves as good as those obtained from solutions of pure potassium iodate.

In order completely to oxidize the iodide in the precipitate, an oxidizing agent must be used which is sufficiently powerful to oxidize the bromide also, thereby exposing any iodide in the interior of a particle to the action of the oxidizing agent. Chlorine water was found to be quite satisfactory. This gives complete oxidation of the iodide and leaves behind an exceedingly fine precipitate of silver chloride which can be removed by filtration. The filtration is made more complete by the addition of a small amount of kieselguhr which coagulates the silver chloride and prevents it from passing through the filter paper.

The next step is the removal of the excess chlorine by the addition of phenol. This reacts immediately with the chlorine but does not react with iodate, and an excess of phenol has no influence on the curves.

The potential at which the curve for iodate occurs is a fairly steep function of *p*H in acid solutions but is independent of *p*H in alkaline solutions. For this reason the solution containing the iodate is made alkaline.

The instrument used in these Laboratories for obtaining the curves is the Fisher Elecdropode.* A simple potentiometer-galvanometer set-up could be used equally satisfactorily. The usual precautions necessary in such work must be observed.[5] The solution being analyzed must be bubbled with nitrogen for several minutes before electrolysis to remove oxygen, and it must be held at constant temperature during the reading.

In calibrating the test with solutions containing a known amount of iodide, it is desirable to obtain the entire wave for iodate by reading

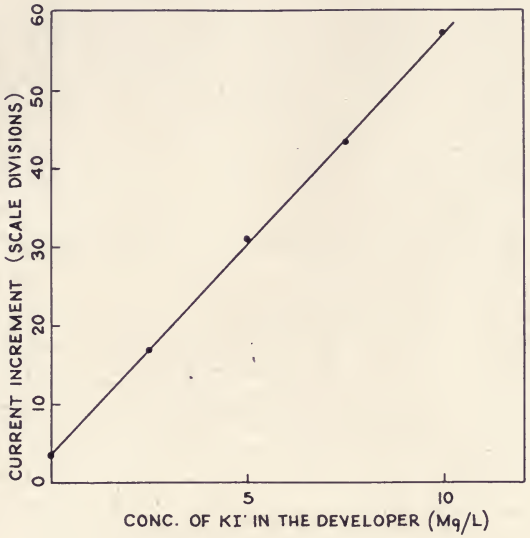

FIG. 2. Calibration curve derived from Fig. 1.

the current at a series of potentials. Such curves are shown in Fig. 1. The wave is completed between -0.9 and -1.4 volts, using a saturated calomel electrode. If, now, the difference in current between these two voltages is plotted against the known concentration of potassium iodide in the developer, a straight line is obtained, as shown in Fig. 2. Once these correct voltages have been established, an unknown can be determined merely by reading the current at these two points and determining the concentration from the calibration curve.

* Fisher Scientific Co., Pittsburgh, Pa. Recent Developments in Laboratory Appliances, Fisher Elecdropode, Cat. No. 9-317.

The exact procedure for the analysis is as follows:

Take a 100-cc sample of developer.

Add 10 cc of 0.5 *N* potassium bromide and 60 cc of conc. sulfuric acid (to insure sufficient precipitate to coagulate).

Allow steam to pass through the solution or boil it until evolution of gas ceases.

To the hot solution add 100 cc of water and 25 cc of 0.5 *N* silver nitrate and pass steam through solution or boil it for a few seconds to aid in coagulation of the precipitate.

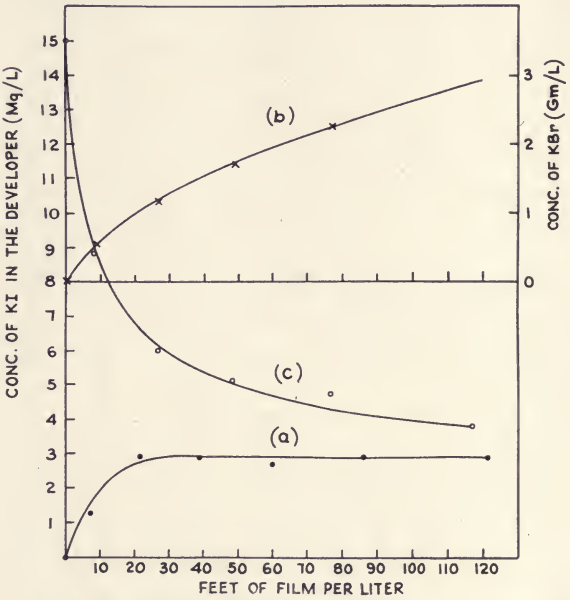

FIG. 3. Iodide equilibrium for Eastman panchromatic negative motion picture film developed for 15 minutes in Kodak *D-76* to a density of 1.0.

Allow the precipitate to settle and pour off the supernatant liquid, leaving the precipitate in the flask.

To the precipitate add 50 cc of 1:1 nitric acid and 250 cc of water; shake up precipitate and allow to settle.

Pour off the supernatant liquid.

Repeat this process with two 250-cc portions of water.

To the precipitate add 50 cc of fresh chlorine water.

Heat until bromine color disappears.

Filter and wash the precipitate with two 5-cc portions of water.

To filtrate add 1.0 cc of 5% phenol, 2 drops of phenolphthalein and enough 2.0 *N* potassium hydroxide to give a pink color (4–10 drops).

Dilute to 100 cc with *p*H 10.0 buffer (sodium carbonate, 4 grams per liter; borax, 4.7 grams per liter).

Bubble nitrogen through the solution, check temperature, and electrolyze with dropping mercury electrode.

Read concentration from calibration curve.

The accuracy obtainable is shown in Table I in which the results of the analyses of developers containing known amounts of potassium iodide are tabulated.

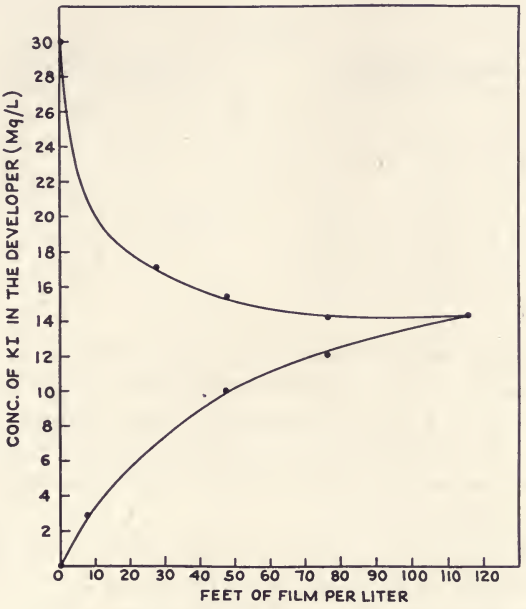

FIG. 4. Iodide equilibrium for Eastman panchromatic negative motion picture film developed for 5 minutes in a positive developer to a density of 1.5.

For developers containing potassium thiocyanate, the procedure just described must be altered slightly. In the normal procedure the thiocyanate is precipitated by the silver and interferes with the curve for iodate. However, the thiocyanate is destroyed slowly by sulfuric acid and if, after the acidification and passing steam through the solution, the developer is allowed to stand for two or three minutes and steam is passed through it again, the thiocyanate is removed

completely. If steam is not readily available, the solution may simply be boiled to give the same result.

Several different types of *MQ* developers containing known amounts of potassium iodide have been analyzed and all gave satisfactory results on the same calibration curve. Consequently, the test need not be calibrated for each formula used, provided no new compounds are present. However, the presence of materials other than the normal constituents of an *MQ* developer, as, for example, potassium thiocyanate, may necessitate some alteration in the procedure.

TABLE I

Potassium Iodide Added (milligrams per liter)	Potassium Iodide Found (milligrams per liter)
2.5	2.6
5.0	5.0
7.5	7.5
10.0	9.9
5.0	Sample 1 4.9
	2 4.9
	3 4.8

This procedure has been used to determine the iodide equilibrium which is established in developers during film aging. As expected, this equilibrium is a function of the developer formula, developing time, density developed, type of emulsion, and possibly other variables. These are still being investigated, but the preliminary results are worthy of some comment.

Eastman panchromatic negative motion picture film was exposed uniformly in a printer so that it gave a density of about 1.0 in 15 minutes of development in Kodak *D-76* developer. At several footage intervals, samples of the developer were analyzed for potassium iodide. The results are shown in Fig. 3 curve *a*, where the amount of potassium iodide in a liter is plotted against the number of feet of film developed per liter. After about 20 feet per liter, the iodide remains constant at about 3 milligrams per liter. Bromide analyses made at the same intervals are shown in curve *b*. To make sure that a true equilibrium had been reached, a quantity of potassium iodide greater than the equilibrium amount was added to the developer and the procedure repeated. The results are shown in curve *c*. The iodide decreases and approaches the same equilibrium that was obtained previously.

In Fig. 4 the iodide equilibrium for Eastman panchromatic film developed for 5 minutes to a density of 1.5 in a positive-type developer is shown to be about 15 milligrams per liter. This demonstrates that, for a given emulsion developed to a given density, the equilibrium is a function of the developer formula. The equilibrium for Eastman positive motion picture film developed for 5 minutes to a density of 0.5 in a positive developer is shown in Fig. 5 to be about 1 milligram per liter.

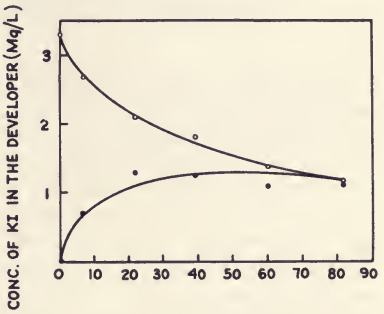

FIG. 5. Iodide equilibrium for Eastman positive motion picture film developed for 5 minutes in a positive developer to a density of 0.5.

Including iodide as one of the important constituents, analyses of a few used developers have led to synthesized formulas which checked photographically with the used developers. This work is being continued in the hope that in the near future it will be possible to predict the photographic activity of a developer solution directly from analyses.

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SYNTHETIC AGED DEVELOPERS BY ANALYSIS*

R. M. EVANS, W. T. HANSON, JR., AND P. K. GLASOE**

Summary.—*The dropping mercury electrode is applied to the problem of analyzing aged photographic developers and new tests are described for elon and hydroquinone. The question of suitable tests for bromide is discussed and it is shown that the bromide test must be independent of chloride. Such a test is described.*

Using these new technics and others it is demonstrated that it is possible and practical by chemical analysis alone to match exactly the photographic characteristics of an aged MQ developer. The only elements necessary for such an analysis are elon, hydroquinone, sulfite, salt concentration, pH, bromide, and iodide. The precision required for the proper analysis for each constituent has been investigated and is reported for three developer-film combinations. In general, the precision required is different for every combination.

It is pointed out that the results show there are no unknowns in aged developers, that they differ from the original formulas only in concentrations and in the presence of iodide as well as bromide. Several useful consequences are suggested.

(I) INTRODUCTION

For the past several years, work has been carried out in these laboratories on the chemical analysis of photographic developers with the hope of being able to predict the action of a photographic developer from its chemical analysis. It is the opinion of many workers that an aged developer is in some way different in its photographic action from a fresh developer made up to correspond to the analysis of the aged one. The data given in this paper show that this difference does not exist under the conditions of these experiments. Developers aged with motion picture positive or negative film have been analyzed and the photographic action of these developers matched by a fresh developer made up to the formula analyzed.

However, before this could be accomplished, it was necessary to make a study of the sensitometric changes caused by a given difference in developer formula in order to know how accurate the analysis had to be. Having determined the required precision of analysis, the

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analytical methods available were examined. If the method was found to give results in error by more than the allowable amount, attempts were made to improve the existing method or a new one was worked out.

(II) EXAMINATION OF DEVELOPER VARIABLES

(*A*) *Experimental.*—Two emulsions were used: Eastman motion picture positive and panchromatic motion picture negative. Sensitometric exposures were made on a type II*b* sensitometer. The exposure on positive film was made with a positive lamp calibrated for a color-temperature of 2660°K with a light blue filter and a gelatin neutral density of 0.3. This gave log $E_{max} = 1.75$. The exposure on negative film was made with a negative lamp calibrated for a color-temperature of 2360°K with a No. *79* filter and a gelatin neutral density of 0.6. This gave log $E_{max} = \bar{1}.92$.

The processing equipment used for these tests consisted of a stainless-steel developing machine provided with removable 4-liter tanks and a separate pair of 25-liter stainless-steel washing tanks.

The developing machine was similar to that described by Jones, Russell, and Beacham[1] but on a smaller scale. It was equipped to agitate six solutions at a time by means of flat paddles permanently attached to the individual tanks and guided both at the top and bottom. Each tank was fitted to hold two film-racks with the paddle passing between them. The paddles were $^5/_8$ inch wide and passed about $^1/_4$ inch from the emulsion surface at a speed of 8 inches per second, completing 25 cycles in one minute.

The racks were frames arranged to hold the strips of film on individual slides. The individual slides were designed to take 12-inch strips with two holes punched at each end, holding them under light spring tension to facilitate loading and to take care of any expansion of the film on wetting. Each rack held four slides.

The darkroom in which the sensitometric work was done was maintained at 70°F and 50 per cent relative humidity. The developing tanks were surrounded by water maintained at 68°F ± 0.1°F by means of a thermostat.

In the washing tanks a strong flow of water and vigorous air agitation were combined to give sufficient washing conditions for twelve racks at a time. After thorough washing, the strips were dried in a forced draft drying cabinet operated at a standard temperature of 110°F.

All sensitometric strips were read with a recording physical densitometer. Four strips were developed on each rack and the curves given are the average of these four strips.

Two types of developer were used, a *D-16* type positive developer and a *D-76* type negative developer. Positive strips were developed in positive and negative developers; negative strips were developed in the negative developer. Four development times were used with each set of developers. With the negative developer the times were 4, 8, 16, and 32 minutes. With the positive developer the times were 1, 2, 4, and 8 minutes.

TABLE I

Variable	Approx. Value in Aged Developer	Per Cent Error Tolerable
Negative Film in Negative Developer		
Elon	1.5	6
Hydroquinone	4.0	50
KBr	1.0	4–5
KI	2.0 mg	10
*p*H	8.4	±0.02 *p*H unit
Positive Film in Negative Developer		
Elon	1.5	3
Hydroquinone	4.0	10
KBr	1.0	4
KI	2.0 mg	10
*p*H	8.4	±0.02 *p*H unit
Positive Film in Positive Developer		
Elon	1.0	10
Hydroquinone	3.0	10
KBr	1.0	10
KI	1.0 mg	20
*p*H	10.00	±0.05 *p*H unit

A sample of negative developer was aged with negative emulsion which had been given a uniform exposure to give a density of approximately 1.0. This aged developer was analyzed to establish the order of magnitude of each of the constituents after such treatment. Then a series of four developers was made up in which one of the analyzed materials, for instance, elon, was varied in concentration above and below the value found on analysis, holding the other concentrations at the analyzed value. Strips of negative emulsion were developed in these developers, and from the set of sensitometric

curves so obtained it was possible to determine how much the elon concentration must change to give a density difference of 0.02 when the amount of elon present is approximately that found in the aged developer. The smallest increment of elon concentration which would cause this effect was used to determine the accuracy needed in the analytical test. Using the formula of the aged developer as a basis, this procedure was repeated for hydroquinone, bromide, iodide, and *p*H. Previous experience indicated that the other constituents of the developer could be neglected.

The above procedure was repeated, using positive film strips instead of negative film strips in negative developer and in positive developer. The data so obtained give the analytical precision necessary to give a check when positive film is developed in negative developer aged with negative film and in positive developer aged with positive film.

The approximate percentage errors which could be allowed in each case are given in Table I.

(*B*) *Discussion.*—It is evident from these results that the variables must be much more closely controlled in negative developer than in positive. *p*H, elon, and bromide are the variables which must be most accurately measured. Hydroquinone is relatively unimportant and iodide can vary by a large percentage although the amounts involved are very small.

(III) METHODS OF ANALYSIS

A method of analysis for constituents of a photographic developer must be simple enough to be readily adapted to routine control work and yet accurate enough to be within the limits which will give a photographic effect. Such a method for hydroquinone in an *MQ* developer has been in use in these laboratories for some time.[2] This test involves the separation of hydroquinone from elon by extraction with ethyl acetate from an acid solution followed by oxidation of the hydroquinone by potassium ferricyanide. The intensity of the brown color so produced is determined on an opacimeter and the concentration of hydroquinone is obtained from a calibration curve. A test for elon was available but the method was rather involved and the results were not trustworthy.

(*A*) *Elon Test.*—The method of separation of elon from a developer solution has been worked out by Pinnow[3] and Lehmann and Tausch.[4] The procedure involves the extraction of elon with an or-

ganic solvent at the *p*H at which elon is the least soluble in water and most soluble in the solvent. However, the methods available for the determination of the amount of elon in the organic solvent have been difficult and time consuming. The success of the test described here lies in the use of a new method of determining the concentration of elon in the extracting solvent. The polarograph is used to make such a determination rapidly and accurately. Since hydroquinone can

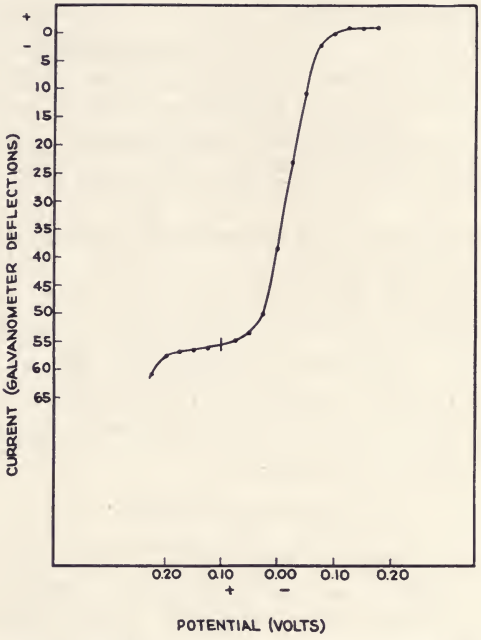

FIG. 1. Polarographic curve for elon in *p*H 8.0 buffer.

also be determined with the same technic, a simple test for hydroquinone was worked out at the same time.

A detailed description of the polarograph and its applications is given in the papers by Kolthoff and Lingane[5] and by Müller.[6] The instrument used in this work was the Fisher Elecdropode. When the polarograph is used in the determination of elon and hydroquinone, the dropping mercury electrode is the anode and the substance being determined is oxidized at the electrode, the current obtained being an anodic current. A typical polarographic wave for elon is shown in

Fig. 1. Since elon and hydroquinone are oxidized at very nearly the same potential on the polarograph, it is necessary to separate them before making the measurement.

The method of separation involves the extraction of hydroquinone with ethyl acetate from an acid solution in which the elon is present as a salt and therefore is insoluble in the organic solvent. The subsequent extraction of elon is accomplished after the *p*H of the solution has been adjusted to a value of approximately 8.0. The complete procedure for elon is as follows:

To a 25-cc sample of developer in a 250-cc separatory funnel, add a few drops of bromphenol blue and 50% sulfuric acid until the color changes to yellow. Add 1.0 cc of this acid in excess. Add 50 cc of ethyl acetate and shake vigorously for a short time. Allow the layers to separate, draw off the water layer, and repeat the process. After the second extraction, draw off the water layer, add to it a few drops of 8.4 indicator (one part 0.1% cresol red, three parts 0.1% thymol blue) and enough 2.0 *N* caustic to obtain a pink-violet color. Dilute the solution to 50-cc with *p*H 8.0 buffer* and extract the elon with 25 cc of ethyl acetate. Add 6 cc of the ethyl acetate layer to a mixture of 30 cc of 95% alcohol and 30 cc of *p*H 8.0 buffer on the polarograph which has had the oxygen removed by bubbling nitrogen through the solution for about five minutes. Record the reading of the galvanometer at a potential of +0.1 volt against the saturated calomel cell. The concentration of elon is then found by reference to a calibration curve for which the data are given in Table II. The galvanometer readings given were obtained at a sensitivity of two times on the Elecdropode. The amount of the ethyl acetate extract to be used will be governed by the amount of elon in the sample. The amounts given above gave nearly full-scale deflection for a concentration of 2.0 grams per liter in the original sample. This gave a maximum sensitivity for the concentration range 0–2.0 grams per liter. In a different concentration range the amounts used should be adjusted to give approximately full-scale deflection for the top concentration. With this method an analysis for elon could be made in about ten minutes with an error of less than 5 per cent. Usually the

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* *p*H buffer formula:

Boric acid	9.9 grams
Potassium hydroxide	0.9 gram
Water to make	1000 cc

results checked within 2–3 per cent. Using this procedure, an examination was made of the factors affecting the extraction of elon.

TABLE II

G/L Elon	Galvanometer Reading at E = +0.10 Volt
0.0	2.5
0.5	23.5
1.0	45.5
1.5	67.0
2.0	88.5

The acidity of the solution at the time of the hydroquinone extraction was found to be very important. If the solution was titrated just to the bromphenol blue end point (pH = 3.5), a small amount of the elon was extracted with the hydroquinone. The addition of 1 cc excess acid made the pH low enough so that no elon was removed. This fact was established by using a developer solution containing no hydroquinone. The ethyl acetate extract after the first acidification was tested for elon. A definite polarographic wave was obtained when the solution was titrated to pH 3.5 and no wave was obtained when the 1 cc excess acid was added. Table III shows the results obtained on a positive type developer with and without the excess acid.

It was found necessary to extract the hydroquinone with two separate portions of ethyl acetate. If only one extraction was performed, some hydroquinone was left in the solution which was extracted at a pH of 8.0 and gave a polarographic wave when the concentration of elon was zero. With the two extractions, the amount of hydroquinone was reduced enough so that no wave was obtained in the elon test when no elon was present.

TABLE III

Acidity	G/L Elon Added	G/L Elon Found
Bromphenol blue end point	2.0	1.35
Bromphenol blue end point	2.0	1.36
Bromphenol blue end point	2.0	1.20
1 cc excess acid over end point	2.0	2.05
1 cc excess acid over end point	2.0	1.97
1 cc excess acid over end point	2.0	2.02

To determine the effect of pH on the extraction of elon, different amounts of potassium hydroxide were added to the acid solution from

which the hydroquinone had been extracted. The amounts of alkali were such that one solution was just at the indicator end point, one had been titrated to the end point and then acid added to give the original yellow, and the third had obviously gone over the end point. The results are given in Table IV. It is apparent from these results that the *p*H of the solution from which the elon is extracted can vary from the value 8.0 much more than would ever be encountered in actual practice, using the indicator given, without vitiating the result.

TABLE IV

G/L Elon Added	*p*H	G/L Elon Found
2.0	8.48	2.00
2.0	7.75	2.04
2.0	9.10	1.99

After making the solution alkaline, it is diluted to a definite volume because it was found that changing the volumes changed the amount of elon extracted. When a dilution was made to 50 cc, the concentration of elon found was 2.0 grams per liter. When the dilution was made to 100 cc, the value obtained was 1.88 grams per liter.

If the test is to be used on aged developers, the results must not be affected by the sulfonates of elon and hydroquinone. Since these substances are present as salts at a *p*H of 8.0, no extraction by an organic solvent is to be expected. Two samples of developer were made up, each containing 2.0 grams per liter of elon. The one containing no sulfonate gave an analysis of 2.0 grams per liter of elon. The other sample containing 8.0 grams per liter of hydroquinone monosulfonate analyzed 1.98 grams per liter of elon.

In routine work it is inconvenient to have a different calibration curve for each different type of developer. It has been shown by Baumbach[7] that the per cent extraction of hydroquinone depends on the sulfite concentration and it follows that the same effect would be found in the case of elon.

Developers containing varying amounts of sulfite and carbonate were analyzed for elon to determine the magnitude of this effect in this method of analysis. The results are given in Table V. The calibration curve was made on a solution containing 45 grams per liter of sodium sulfite and 30 grams of sodium carbonate. The column represented as grams per liter of sodium sulfate gives the calculated amount of sodium sulfate equivalent to the sodium sulfite and sodium carbonate present.

TABLE V

G/L Sodium Sulfite	G/L Sodium Carbonate	G/L Sodium Sulfate	G/L Elon	
			Added	Found
20	0.0	22.5	2.00	1.90
20	8.9	32.5	2.00	1.90
40	0.0	45.0	2.00	1.99
40	26.7	75.0	2.00	1.99
45	30.0	85.3	2.00	2.00
80	0.0	90.2	2.00	2.05
100	0.0	112.0	2.00	2.05
100	40.0	145.0	2.00	2.07
80	62.3	160.2	2.00	2.07

These results indicate that although an increase in salt concentration increases the amount of elon extracted, the same calibration curve could be used for salt concentrations equivalent to 45 to 160 grams per liter of sodium sulfate.

Some difficulty was experienced at first in getting a sharp break in the current-voltage curve obtained with an ethyl acetate extract. At that time the electrolyzed solution was buffered to *p*H 10. It was found that if the *p*H of the solution was 8.0 instead of 10, the curve obtained had a good break. The alcohol in the solution is necessary to make the ethyl acetate miscible with the buffer mixture. Sodium sulfite or any halides will interfere with the polarographic wave. For this reason, the calomel cell saturated with chloride is connected to the electrolysis cell by means of an agar bridge saturated with potassium nitrate. Also, one must be very careful not to introduce any of the water solution containing sulfite into the electrolyzed solution.

(*B*) *Hydroquinone Test.*—A polarographic wave similar to that of elon can be obtained with hydroquinone in the same buffer-alcohol mixture used in the elon test. However, if the ethyl acetate solution of hydroquinone obtained in the extraction from an acidified developer is added to the buffer-alcohol mixture, no wave is obtained. This is due to the fact that the ethyl acetate dissolves a large amount of sulfur dioxide from the acid solution which then forms sulfite in the alkaline mixture. The presence of this sulfite will eliminate the break in the current-voltage curve. This sulfur dioxide can be removed by washing the ethyl acetate extract with an alkaline solution. The ethyl acetate solution so treated is added to the buffer-alcohol mixture and a good polarographic wave is obtained.

The procedure used is as follows: To a 25-cc sample of developer in a 250-ml separatory funnel, add a few drops of bromphenol blue

and then add 50% sulfuric acid until the color changes to yellow. Add 1 cc of the acid in excess. Add 50 cc of ethyl acetate and shake vigorously for a few moments. Allow the layers to separate and draw off the water layer which will be used for an elon analysis if it is desired. To the ethyl acetate solution add 50 cc of a solution composed of 100 grams sodium sulfite, 10 grams boric acid, and 1.0 gram potassium hydroxide in one liter. Shake up this mixture well and allow the layers to separate. Add 2 cc of the ethyl acetate extract to a mixture of 30 cc 95% alcohol and 30 cc of *p*H 8.0 buffer through which nitrogen has been bubbled for about five minutes. The current at +0.10 volt against the saturated calomel electrode is recorded and the concentration of hydroquinone obtained from a calibration curve previously made.

The effect of a change in total salt concentration is less in the case of hydroquinone than it was in the case of elon. Table VI shows the results of analyses for hydroquinone in developers of varying salt content.

TABLE VI

Concentration of Sodium Sulfite G/L	Concentration of Sodium Carbonate G/L	Concentration of Sodium Sulfate G/L	Concentration of Hydroquinone Added	Concentration of Hydroquinone Found
10	0	11.2	5.0	5.05
100	0	112.0	5.0	5.0
100	80	203.0	5.0	4.9

The first ethyl acetate extraction of the acidified developer removes approximately 92 per cent of the hydroquinone. Baumbach[7] has given the value of extraction of hydroquinone with ethyl ether as 60 per cent. This work indicates that ethyl acetate is a more effective extraction solvent. The ethyl acetate extraction of elon removes only about 80 per cent of the elon present. This difference in extraction coefficient explains the greater effect of changing salt concentration on the analytical result in the case of elon.

When these two tests are performed on the same 25 cc of developer they can be completed in 15 to 20 minutes with an accuracy of 5 per cent or better. Before a calibration curve is made, a few trial analyses should be performed in which the whole current-voltage curve is plotted and a point about midway in the flat portion of the curve chosen as the potential at which readings will be made.

(*C*) *Bromide Analysis.*—The test for bromide[2] which involved a titration with an adsorption indicator was considered to be sufficiently accurate and it was used in this work for some time. However, as Evans and Hanson[2] pointed out, this method will also titrate chloride with the bromide so that if any chloride is present, the bromide analysis will be high. Using a silver electrode, a potentiometric titration of an aged developer solution which had been acidified gave two

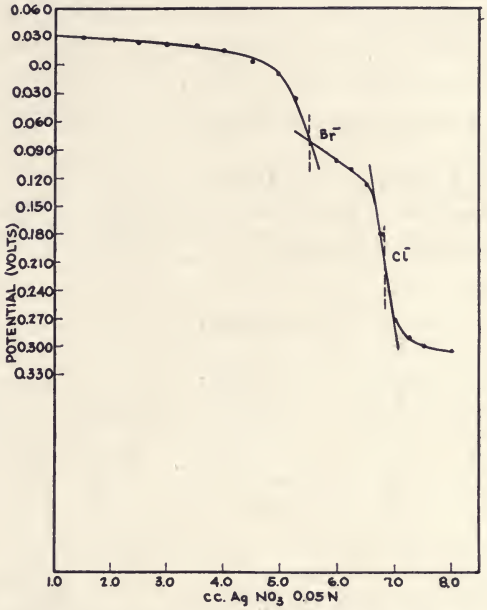

FIG. 2. Potentiometric titration of film aged developer—silver electrode.

breaks (Fig. 2) indicating the presence of chloride as well as bromide. Although the amount of chloride is small, there is enough to make the bromide analysis in error by 10–15 per cent.

The photographic influence of the presence of chloride in the two developers used was investigated over the range of concentrations from 0 to 8 grams per liter and it was found to have no effect. However, the sensitivity to bromide was such that if the *bromide analysis included the chloride so that in the synthetic developer the chloride was replaced by an equivalent amount of bromide, an appreciable error would result.* Fig. 3 shows the photographic result obtained in such a

case. By the adsorption indicator method of analysis the concentration of potassium bromide found was 1.4 grams per liter while the value obtained by the potentiometric titration method was 1.07 grams per liter. This finding explained the failure to obtain matching sensitometric curves for aged and fresh developers, using the adsorption indicator method of analysis.

The analytical method for bromide in an aged developer which was finally used is as follows: To 25 cc of developer, which has been

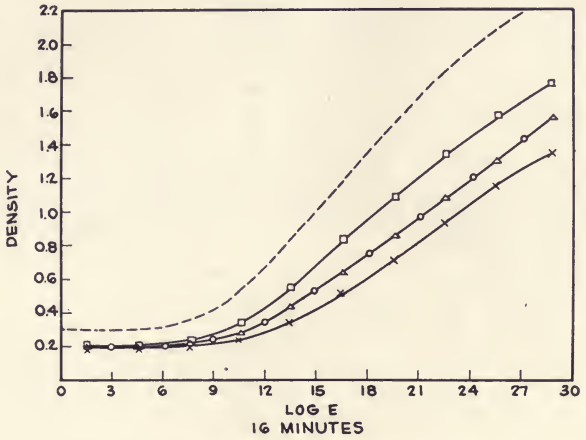

FIG. 3. Negative film in negative developer.
– – – Fresh developer
○ Aged developer
△ Synthetic aged developer
□ Synthetic aged developer without iodide
× Synthetic aged developer. Bromide analysis by adsorption indicator.

heated to boiling to complete the reduction of any silver held in solution by the sulfite and then cooled,* add 10 cc of 50% sulfuric acid.

Pass steam through the solution or boil it to drive off the dissolved sulfur dioxide.

Add 20 cc of a solution of sodium acetate, 150 grams per liter, to the above solution and titrate the solution with 0.05*N* silver nitrate, using a silver electrode and a regular potentiometric set-up for potentio-

* This step is necessary only with low-energy high-solvent developers such as *D76*.

metric titrations.* A plot of the points will readily show the break due to bromide. This method requires more time than the indicator method, but with a little experience an analysis can be made in about fifteen minutes. One gram of potassium bromide per liter can be determined with an accuracy of two per cent.

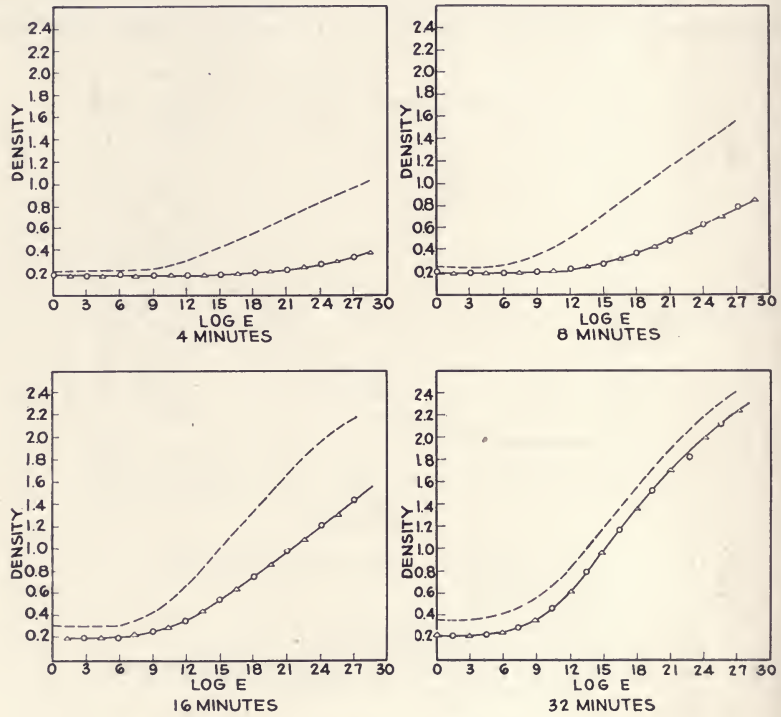

FIG. 4. Negative film in negative developer.
– – – Fresh developer
○ Aged developer
△ Synthetic aged developer

(*D*) *pH.*—The *p*H of the developer was measured with a Beckman Laboratory Model *p*H meter. Since in matching an aged developer with a fresh one it was not important to have the absolute

* In this work the Fisher Elecdropode was used by simply substituting the silver electrode for the dropping mercury electrode and inserting a tap key in the circuit so that the galvanometer could be used as a null-point instrument.

value of *p*H but merely to have the same *pH*, the sodium-ion corrections for the glass electrode were neglected. It was found to be possible to get the two developers to the same *p*H within 0.02 *p*H unit if care was exercised.

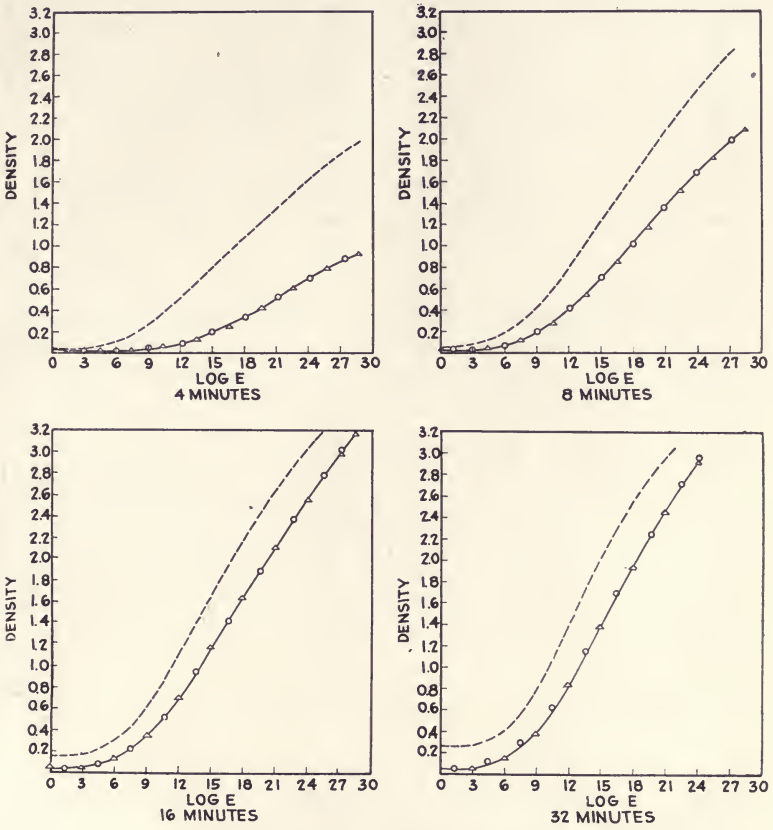

FIG. 5. Positive film in negative developer.
– – – Fresh developer
○ Aged developer
△ Synthetic aged developer

(*E*) *Iodide.*—The iodide test used was the one described in a previous paper.[8] The importance of an analysis for iodide is shown in Fig. 3. The amount of iodide found in this aged developer was 3.5 milligrams of potassium iodide per liter.

(IV) MATCHING OF AGED AND FRESH DEVELOPERS

Having then determined the errors in analysis which could be tolerated and having obtained methods of analysis which would give

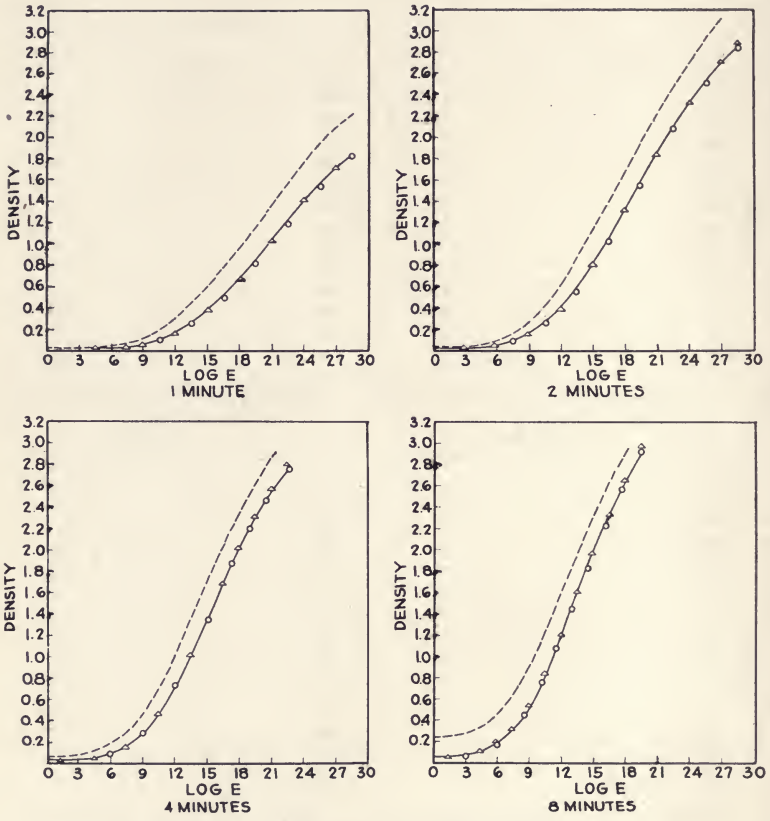

FIG. 6. Positive film in positive developer.
– – – Fresh developer
○ Aged developer
△ Synthetic aged developer

results within these limits, the next step was the matching of the sensitometric curves obtained with an aged and a fresh developer.

(*A*) *Aging of Negative Developer with Negative Film.*—Two hundred feet of negative film which had been flashed to give a developed density of about 1.0 were developed in 5 liters of fresh negative developer for fifteen minutes. The developer then stood overnight and

was analyzed the next morning for elon, hydroquinone, bromide, and iodide. Then a fresh developer was made up using these analytical values. After about an hour, the *p*H of the aged developer was measured and acid added to the fresh developer to bring it to the same *p*H as the aged developer. Within a few hours exposed sensitometric strips of negative film were developed in each of these developers, using the technic described in Part I and the sensitometric curves compared (Fig. 4).* A third developer aged with negative film was used to develop sensitometric strips of positive film and compared to a fresh one made up to the analysis of the aged developer (Fig. 5).

(*B*) *Aging of Positive Developer with Positive Film.*—The same procedure given above was used in aging a positive developer with positive film which had been given a uniform exposure to give a developed density of about 1.5. In order to build up the bromide concentration to a value approximating that found in actual practice, some of the film was developed to completion in the light, otherwise very large quantities of film would be required. Three samples of positive developer which contained no potassium bromide were used and enough film was run through them to give bromide concentrations of 1.52, 2.28, and 3.80 grams per liter. Analyses for hydroquinone, elon, and potassium iodide were performed, fresh developer was made up, the *p*H of fresh and aged developers adjusted to the same value, and exposed sensitometric strips of positive film were developed in the two developers. The results obtained with the sample containing 2.28 grams of potassium bromide per liter are given in Fig. 6.

SUMMARY

This work, as far as it goes, indicates that in a used photographic developer there are no unknown compounds which affect its photographic properties. An aged developer simply contains less of the developing agents than before, and iodide and bromide have been added with a possible change in *p*H.

This fact is of vital importance to control work since it is now possible to state that an accurate analysis specifies the photographic

* Comparisons made between developers which were used within a few hours and some which were allowed to stand overnight in stoppered bottles showed no difference.

properties of the solution for a given use. Perhaps a word of caution should be added, however. The result obtained when an exposure on a photographic material is developed depends not only on the developer formula of the film and the exposure but also, to just about as great an extent, on the physical conditions under which the development takes place. While chemical analysis can and will show whether or not a developer will give the same results as another developer when used on the same equipment, it does not follow that if two developers are identical chemically they will give matched results on two different developing machines. Temperature, agitation, aeration, fogging agents, direction of circulation and rate of drying all are capable of making just as great differences as a 5 or 10 per cent change in the elon concentration. For the control man whose job it is to maintain a particular developing machine constant, however, it has been demonstrated that if the elon, hydroquinone, bromide, iodide, and *p*H are correct the developer is chemically under control as far as the normal chemicals which affect the photographic results are concerned. Sudden onset of fog such as that due to sulfide bacteria and the like, of course, are not checked. However, knowledge that all normal chemicals are correct speeds the discovery of the actual source of trouble.

Another aspect of these results should be noted. It has been customary in the past to give the formulas used in various laboratories as though the fresh mixes were the important ones. It has long been known, of course, that they had little relation to the aged ones and would give different results if they were placed in the machines. Knowing now what the essential differences are, it becomes a simple matter to state accurately by analysis just what the actual developer is. A comparison of these actual formulas will eventually lead to quantitative technics of measuring the physical-photographic differences between different types of machines.

For the practical laboratory man interested in maintaining his machine constant at all times and under all circumstances, this work suggests a valuable possibility. It is customary practice in most laboratories to shut down the machine occasionally for cleaning and for dumping the solutions, or at least part of them. Starting up the machine then has involved aging down the fresh solutions to the point where they matched previous results and getting the bath back to the control point. This is time-consuming and difficult, so much so, in fact, that many laboratories find it quite out of the question and

run for years with continuous replenishment without ever dumping the solutions. Both situations are bad and can now be avoided. If the actual formulas in use are known by analysis, a fresh mix which analyzes the same when it is placed in the machine, will give the same results without aging or any other special handling. Note, however, that it is the concentration of the compounds after the solution reaches the machine which must be the same as the standard. A great deal of elon and hydroquinone can be lost by oxidation while a machine is being filled. Note, also, that iodide as well as bromide must be added to such a mix. The same replenisher formulas should be made for such a mix as were used on the old batch.

Acknowledgment.—The thanks of the authors is due to Miss Jeannette Klute and Mr. John Murphy for their assistance.

DEVELOPER FORMULAS

Negative Developer

	Fresh	*Aged*	
		I	II
	G/L	G/L	G/L
Sodium sulfite	100	100	100
Elon	2.0	1.45	1.47
Hydroquinone	5.0	3.7	4.40
Borax	2.0	2.0	2.0
Potassium bromide		1.07	0.98
Potassium iodide		3.5 mg/l	1.8 mg/l

(I) Used to develop negative film.
(II) Used to develop positive film.

Positive Developer

	Fresh	*Aged*
	G/L	G/L
Sodium sulfite	45.0	45.0
Elon	1.0	0.92
Hydroquinone	4.0	2.75
Sodium carbonate	30.0	30.0
Potassium bromide	1.0	2.28*
Potassium iodide		0.4 mg/l

*Developer contained no bromide before aging.

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CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C., at prevailing rates.

American Cinematographer

22 (December, 1941), No. 12

Using Arcs for Lighting Monochrome (pp. 558–559)	G. Toland
Why Overlook the Set-Miniature? (pp. 560–561, 588)	V. Korda
"Puppetoons"—George Pal's Three-Dimensional Animations (pp. 563, 588)	A. Wyckoff
Making Wipes in the Printer (pp. 574–575, 593)	H. Zech

23 (January, 1942), No. 1

Technical Progress in 1941 (pp. 6–7, 45–46)	
Increasing Focal Depth with the IR System (pp. 8–9, 38–44)	A. N. Goldsmith
Coordinating Exposure-Meter and Processing for Effect-Lightings (pp. 10, 38)	J. J. Mescall
The Air Corps' Newest Camera Gun (pp. 11, 37–38)	R. N. Haythorne
Determining the Sun's Angle for Any Location (pp. 12–13, 37)	L. Kuter
Lamps—Without Priorities (pp. 22–23, 34, 36)	W. Stull

British Kinematograph Society Journal

4 (October, 1941), No. 4

Demonstrations of New Apparatus (pp. 143–149)	
Further Notes on a Kodelon Developer (pp. 150–154)	I. D. Wratten and G. Levenson
Electricity in the Film Studio (pp.155–166)	F. V. Hauser

Educational Screen

20 (December, 1941), No. 10

Motion Pictures—Not for Theaters (pp. 427–429), Pt. 32	A. E. Krows

Electronic Engineering

14 (December, 1941), No. 166

Colour in Sound, a Study from the Psychological Viewpoint (pp. 547–548)	E. L. Trist

International Photographer
13 (January, 1942), No. 12
Outdoor Color Studio (p. 18)

International Projectionist
16 (October, 1941), No. 10
Multiple-Speaker Reproducing Systems for Sound Motion Pictures (pp. 9–12, 14) — H. I. REISKIND
Warner's "Vitasound" Theater System (pp. 14–16) — N. LEVINSON AND L. T. GOLDSMITH
Enlarging 16-Mm Kodachrome to 35-Mm Technicolor (p. 17) — W. STULL
Magnetic Recording and Reproduction (pp. 18, 20)

Motion Picture Herald (Better Theaters Section)
146 (January 10, 1942), No. 2
Getting Efficient Cooling in Spite of Priorities (pp. 16–17, 24) — C. F. BOESTER
Making the Theater a "Safe" Place in Wartime (pp. 18–20)

FIFTY-FIRST SEMI-ANNUAL CONVENTION

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TENTATIVE PROGRAM

MONDAY, MAY 4, 1942

9:00 a.m. *Hotel Lobby;* **Registration**
12:30 p.m. *Terrace Room;* **Informal Get-Together Luncheon**
Addresses by prominent Hollywood members of the motion picture industry; names to be announced later
2:00 *Blossom Room;* **General Session**
8:00 *Blossom Room;* **Technical Session**

TUESDAY, MAY 5, 1942

9:30 a.m. *Hotel Lobby;* **Registration**
This morning will be devoted to a studio visit or other activity to be announced later
2:00 p.m. *Blossom Room;* **Technical Session**
8:00 *Blossom Room;* **Technical Session**

WEDNESDAY, MAY 6, 1942

9:30 a.m. *Hotel Lobby;* **Registration**
10:00 *Blossom Room;* **Technical Session**
2:00 p.m. The afternoon will be left open for a possible trip, to be announced later, or for recreation
8:30 *Blossom Room;* **Fifty-First Semi-Annual Banquet and Dance;** details to be announced later

THURSDAY, MAY 7, 1942

10:30 a.m. *Hotel Lobby;* **Registration**
Open morning
2:00 p.m. *Blossom Room;* **Technical Session**
8:00 *Blossom Room;* **Technical Session**

FRIDAY, MAY 8, 1942

10:00 a.m. *Blossom Room;* **Technical Session**
2:00 p.m. *Blossom Room;* **Technical Session**
8:00 *Blossom Room;* **Technical Session**

Adjournment of the Convention

HEADQUARTERS

The Convention headquarters will be at the Hollywood-Roosevelt Hotel. Excellent accommodations have been assured by the hotel management at the following *per diem* rates:

One person, room and bath	$3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, one person	8.00–14.00
Parlor suite and bath, two persons	12.00–16.00

Room reservation cards will be mailed to the membership early in April and should be returned to the hotel immediately to be assured of satisfactory accommodations.

Indoor and outdoor parking facilities adjacent to the hotel will be available for those who motor to the Convention.

Golfing privileges may be arranged by request of the hotel management or at the registration headquarters.

Registration headquarters will be in the hotel lobby. All members and guests attending the Convention will be expected to register and receive their Convention badges. The registration fees are used to defray the expenses of the Convention, and coöperation in this respect is requested. Identification cards will be supplied, which will serve as admittance to all scheduled or special sessions, studio visits, and trips, and several *de luxe* motion picture theaters on Hollywood Boulevard in the vicinity of the hotel.

Members planning to attend the Convention should consult their local railroad passenger agents regarding train schedules, rates, and stop-over privileges *en route*. For a stop-over at San Francisco the Convention Committee recommends the Mark Hopkins Hotel, on "Nob Hill." Accommodations may be arranged with Mr. George L. Smith, manager of this hotel.

An interesting color-print exhibit will be an adjunct to the Convention and will be open to the public and delegates during the five days of the Convention.

The Convention hostesses promise an interesting program of entertainment for the visiting ladies. A reception parlor will be provided as their headquarters at the hotel.

Note: The Pacific Coast Section officers and managers gave serious consideration to the question of holding the 1942 Spring Convention at Hollywood, and have decided to proceed with arrangements for the meeting. The motion picture industry plays an essential part from the exhibiting and engineering viewpoint in upholding the morale of the general and theater-going public in the present crisis, and accordingly the Convention and Local Arrangements Committees are proceeding with their plans. However, if later deemed advisable in the National interest, the Convention will be subject to cancellation thirty days prior to the announced Convention dates.

W. C. KUNZMANN,
Convention Vice-President

SOCIETY ANNOUNCEMENTS

FIFTY-FIRST SEMI-ANNUAL CONVENTION

HOLLYWOOD-ROOSEVELT HOTEL
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MAY 4–8, 1942

The Board of Governors, the Board of Managers of the Pacific Coast Section, and the Convention Arrangement Committee have decided to hold the next Convention at Hollywood, May 4th to 8th, inclusive, as planned, subject to cancellation upon thirty days' notice if deemed necessary in the national interest. Committees of the Convention have begun to make their plans for the various sessions, and the Papers Committee has a number of interesting symposiums and presentations under consideration. Details concerning the sessions and the various Committees will be found on p. 209 of this issue of the JOURNAL.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, the following applicants for membership were admitted into the Society in the Associate grade:

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Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted.

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	No.	Price
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	34	2.50
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	36	2.50
1929	37	3.00
	38	3.00

Beginning with the January, 1930, issue, the JOURNAL of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers of all issues are available at the price of $1.00 each, a complete yearly issue totalling $12.00. Single copies of the current issue may be obtained for $1.00 each. Orders for back numbers of *Transactions* and JOURNALS should be placed through the General Office of the Society and should be accompanied by check or money-order.

SOCIETY SUPPLIES

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

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

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

Motion Picture Standards.—Reprints of the *American Standards and Recommended Practices* as published in the March, 1941, issue of the JOURNAL; 50 cents each.

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

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

Test-Films.—See advertisement in this issue of the JOURNAL.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

VOLUME XXXVIII • • • MARCH, 1942

CONTENTS

The Color of Light on the Projection Screen
M. R. Null, W. W. Lozier, and D. B. Joy 219

New 13.6-Mm Carbons for Increased Screen Light
M. T. Jones, W. W. Lozier and D. B. Joy 229

The Consumption of the Positive Arc Carbon
H. G. MacPherson 235

Stabilized Feedback Light-Valve
W. J. Albersheim and L. F. Brown 240

A Constant-Torque Friction Clutch for Film Take-Up
W. Hotine 256

Recent Developments in Projection Mechanism Design E. Boecking and L. W. Davee 262

Report of the Studio Lighting Committee 281

Adventures of a Film Library R. Griffith 284

Work Simplification—Essential to Defense
A. H. Mogensen 295

Current Literature 300

Fifty-First Semi-Annual Convention, Hollywood, Calif., May 4–8, 1942 302

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THE COLOR OF LIGHT ON THE PROJECTION SCREEN*

M. R. NULL, W. W. LOZIER, AND D. B. JOY**

Summary.—*Spectral energy distribution measurements of the light at the center of the projection screen have been made for a number of arc lamp and carbon combinations employed in motion picture projection. ICI color-coördinates and color-temperatures have been calculated and show that the various high-intensity combinations give chromaticities and color-temperatures which agree closely among themselves. The spectral-energy distribution data of both low and high-intensity lamps and carbons show marked similarity to black-body curves.*

The various combinations of carbon arcs and lamps employed for motion picture projection have been discussed before this Society on previous occasions. The characteristics of the arcs themselves and also their performance with complete optical systems have been considered and important factors concerning the light on the projection screen have been determined. The growth of colored motion pictures has led to increased emphasis on the importance of color and we have undertaken a program of study of the color of the light on the projection screen in terms of modern methods of measurement and specification.

A few years ago, members of the Research Laboratory of our Company made measurements of the spectral-energy distribution of the light from carbon arcs used for photography in motion picture studios and also for projection in motion picture theaters. The results of this work have been presented by Bowditch and Downes.[1, 2, 3] These measurements pertained to the direct radiation from the carbon arcs and in most cases referred to the crater radiation only. It was realized that in the case of carbon arcs used for projection, the passage of the light through the optical system would result in the selective absorption of light in certain wavelength regions and so alter the resultant color on the motion picture screen. Also the variations between the color of the light emitted from the crater and the adjacent

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** National Carbon Company, Fostoria, Ohio.

portions of the arc are difficult to assess as regards their influence upon screen light. Since the factors described above are variables dependent upon the characteristics and adjustment of each particular optical system, their effect was not included in the earlier general description of the radiation from the arc itself. In each installation, however, the effect of the projector optical system on the color of the light must be recognized and we have recently evaluated the spectral-energy distribution of the light on the projection screen for a number of individual cases of lamps, optical systems, and carbons. These results give us new and interesting information and, so far as we know, represent the first measurements of the spectral-energy distribution on the projection screen.

The various projector arcs discussed below were burned in their respective lamps with the customary optical systems, illuminating a bare film aperture. A standard projection lens was used to focus an image of the film aperture on a miniature projection screen about one foot wide. The monochromator employed for measuring the spectral-energy distribution was placed with its entrance slit at the center of the illuminated projection screen. By means of the monochromator and associated thermopile and galvanometer we are able to determine the relative amounts of energy in the various wavelength bands throughout the visible spectrum. While this method of measurement includes the effect of the lamp and projector optical systems upon the color of the light, it does neglect the influence of the projection screen and the motion picture film. If the projection screen is non-selective and reflects equal proportions of all wavelengths falling upon it, then it will not alter the form of the spectral-energy distribution curve or the color of the projection light. If the screen does have some spectral selectivity, the effect can be calculated by employing the spectral reflectance curve of the screen material in combination with spectral-energy distribution data reported in this paper. Similarly, the spectral transmission characteristics of the motion picture film can be combined with the data of this paper to determine the overall effect on the screen. The spectral-energy distribution data should therefore prove of particular value to those interested in the further development of colored motion pictures.

Previous experience with carbon arc projector lamps has shown that when the arc is maintained at the correct distance from the reflector or condenser lens the color over the projection screen has a uniform visual appearance. When the carbons are displaced from the

position of correct adjustment, there result changes in the intensity and distribution of the light on the screen which have been discussed in earlier publications.[4, 5, 6] If these displacements become severe enough they may first produce slight changes in color over the entire screen and, later, differences in color between different portions of the screen. It is hoped in the future to be able to present measurements on the extent of these color variations. However, for the measurements reported below, the carbon position has been maintained at

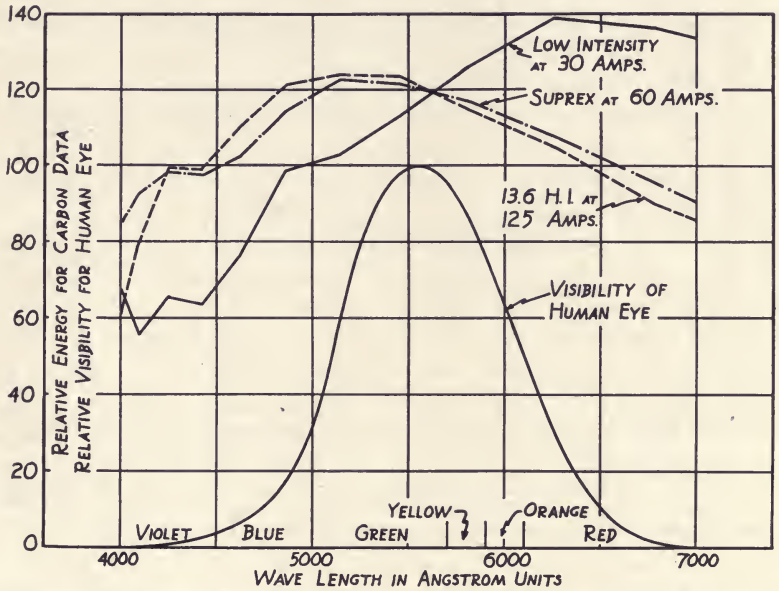

FIG. 1. Spectral-energy distribution data for light at center of projection screen with low-intensity lamp at 30 amps, Suprex-type lamp at 60 amps, and condenser-type lamp at 125 amps, with heights of curves adjusted to give equal foot-candles.

the correct position to give uniform visual color over the screen and measurements have been carried out only at the center of the screen.

The visible wavelength range extends from 4000 to 7000 Å. In Fig. 1 is shown the spectral-energy distribution over this visible range of light on the projection screen for three widely used projector lamps and arcs. These include the low-intensity lamp, the Suprex type lamp, and the condenser type lamp burning the 13.6-mm high-intensity carbon at 125 amperes. These spectral-energy distribution measurements tell nothing about the lesser amount of light obtained from

the low-intensity system; in fact, for the purposes of this paper the heights of the three curves have been adjusted so they are on the basis of equal visible light. The spectral-energy distribution of the screen light from the low-intensity lamp shows the red radiation as the most plentiful, and relatively lesser amounts of green and blue. The two high-intensity lamps show on the screen a more even balance of energy among the different wavelengths with actually a slight preponderance in the green region.

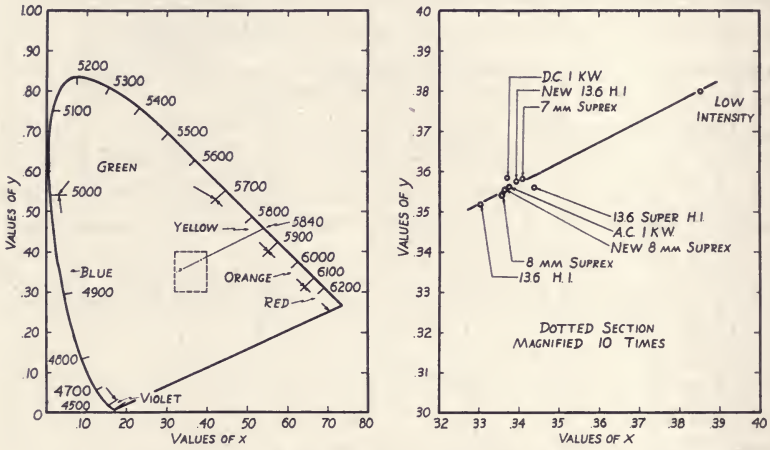

FIG. 2. Chromaticity diagram showing ICI color-coördinates of various lamp and carbon combinations. The right-hand figure shows a tenfold enlargement of the indicated portion of the left-hand figure.

These spectral-energy distribution data can be used to derive further quantities which are widely used in discussion and comparison of visual colors. Two such bases of comparison are (*1*) the chromaticity diagram, and (*2*) comparison with a black body.

Chromaticity Diagram.—The use of the ICI chromaticity diagram has been illustrated in a number of publications in recent years.[7, 8, 9] According to this procedure, it is possible to calculate from the spectral-energy distribution of a light-source or illuminated object three numbers or color-coördinates which specify its color.[10] These are the so-called ICI trichromatic coefficients x, y, and z. Since the sum of these trichromatic coefficients is unity, only two of them are necessary to describe the color. The coefficients x and y can be plotted as coordinates on a chromaticity diagram as shown in Fig. 2. The color-

coördinates of all pure spectrum colors are known, and when plotted in this manner fall on the curved boundary of this diagram, with the wavelengths of the various parts of the spectrum indicated in Å. All composite colors, which are in reality composed of varying proportions of pure spectrum radiation, will fall within the curved boundary of the chromaticity diagram of Fig. 2.

The ICI color-coördinates of the various light-sources studied in our tests have been calculated and are given in Table I. Values for representative currents for each of the combinations shown in Table I have been plotted in Fig. 2. It is apparent, particularly from the enlargement shown at the right-hand side of Fig. 2, that the colors of the screen light from all the high-intensity arc lamps are in a closely bunched group which is distinctly separated from the color of the low-intensity arc lamp. This chromaticity diagram has the useful property that if the points representing any two component colors are connected by a straight line, then the points representing all possible combinations of these components will lie on that straight line. For example, on Fig. 2, a straight line drawn from the center of the group of "high-intensity" points through the "low-intensity" point intersects the boundary of the diagram at 5840 Å, in the yellow part of the spectrum. This explains the color differences observed when these two light-sources are projected side by side. The "low-intensity" color can be obtained by adding yellow light of wavelength 5840 Å to the "high-intensity" light and therefore the "low-intensity" light appears yellow compared to the "high-intensity."

Comparison with Black-Body Radiation.—It is common procedure to compare the color of a so-called continuous-type light-source with that of a theoretical black body, the quality of whose radiation depends only upon the temperature. This comparison is expressed as the color-temperature of the light-source, which is defined as the temperature at which a black body would have to be maintained in order that its radiation would most nearly match the color of the source in question. Using this method of comparison, the color-temperatures of the screen light from the various combinations of lamps and carbons have been determined[11] as shown in Table I. We note that the color-temperature of the screen light from the low-intensity lamp is 3870°K, while the high-intensity screen light ranges from 5020° to 5620°K. The color-temperatures of the Suprex type, the "One Kilowatt" a-c and d-c, and the condenser-type lamps over their recommended current ranges all fall within this range.

TABLE I

Color Measurements at Center of Screen with Complete Optical System; Carbons Positioned to Give Uniform Visual Color over Screen

Trim	Lamp and Optical System*	Amps	ICI Trichromatic Color Coördinates x	ICI Trichromatic Color Coördinates y	Color-Temp. at Center of Screen	Color-Temp. of Bare Arcs**
12-mm—8-mm SRA	Low-Intensity Lamp and Mirror	30	0.3853	0.3800	3870°K	3570°K
7-mm "Suprex" Pos. 6-mm "Orotip" "C" Neg.	"One K.W." d-c Lamp and Mirror	40	0.3370	0.3584	5300	
7-mm—7-mm "Suprex" Pos.	"One K.W." a-c Lamp and Mirror	52	0.3380	0.3532	5260	
		59	0.3375	0.3560	5300	
		65	0.3346	0.3554	5420	
7-mm—6-mm "Suprex"	Suprex Lamp and Mirror	42	0.3452	0.3638	5020	5800
		45	0.3408	0.3583	5180	
		50	0.3486	0.3660	5060	5950
8-mm—7-mm "Suprex"	Suprex Lamp and Mirror	56	0.3371	0.3564	5320	6250
		60	0.3356	0.3540	5380	
		65	0.3308	0.3515	5570	6400
New 8-mm—7-mm "Suprex"	Suprex Lamp and Mirror	65	0.3364	0.3554	5340	
		70	0.3386	0.3612	5270	
13.6-mm H.I. Proj.	High-Intensity Lamp and Condensers	120	0.3298	0.3502	5620	
		125	0.3302	0.3517	5610	5800
		130	0.3223	0.3560	5480	
New 13.6-mm H. I. Proj.	High-Intensity Lamp and Condensers	125	0.3288	0.3445	5600	
		145	0.3392	0.3576	5240	
13.6-mm Super H. I.	High-Intensity Lamp and Condensers	180	0.3442	0.3599	5050	5480

* All lamp mirrors and condensers were of comparable manufacture by the same maker. The projection lens was 5.5-inch $f/2.5$.

** Values for crater radiation.[3]

The specifications of light-sources by chromaticity or color-temperature are visual ones, based upon eye response and not upon the spectral-energy distribution alone. Thus two sources may match perfectly in chromaticity or color-temperature, even though the spectral-energy distributions of their radiant energies are widely different.

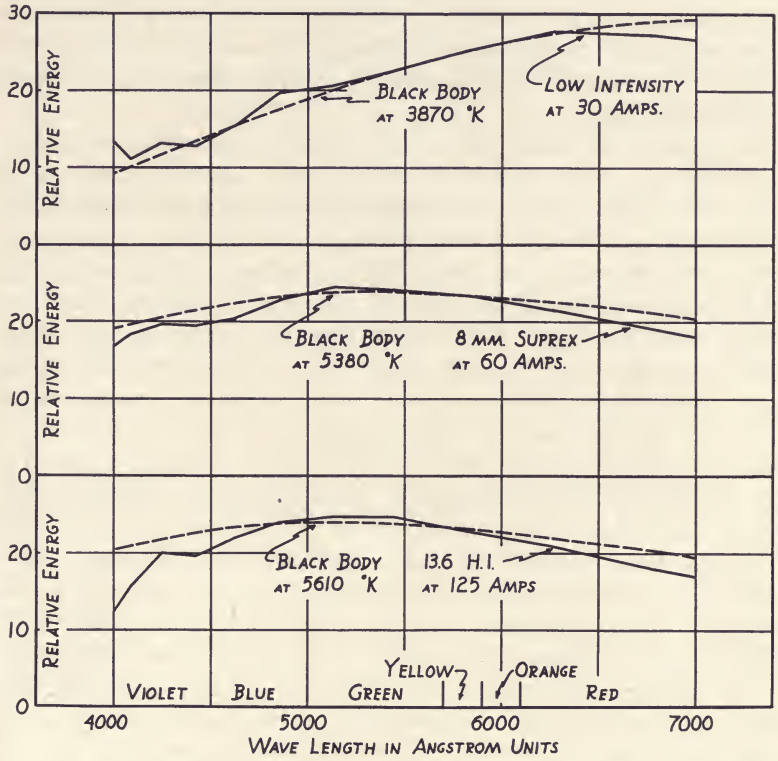

FIG. 3. Comparison of spectral-energy curves of Fig. 1 with black-body curves of nearest chromaticity, with ordinates adjusted to give equal foot-candles.

Therefore the practical significance of chromaticity and color-temperature is limited. For a black body, of course, the temperature completely specifies the energy distribution as well as the color. It is interesting to note that on account of the close correspondence of the carbon arc light-sources under consideration to black-body sources, the color-temperature is an unusually good measure of the spectral-energy distribution in these cases as well. Fig. 3 shows

the spectral-energy distribution of the "low-intensity," "Suprex," and condenser-type high-intensity screen light in comparison with spectral-energy distribution curves for black bodies at the same color-temperature and same candle-power. The spectral-energy distribution of the screen light from the low-intensity projector lamp corresponds quite closely through the visible to that of a black body at the same color-temperature. With the high-intensity lamps the similarity is still almost as good though these arcs have slightly less energy in the red and blue and more in the green than the corresponding black bodies.

In Table I are shown also color-temperature values obtained in the earlier measurements on the direct crater radiation from some of these arcs.[3] This has been unaltered by transmission through any optical system and comparison of these values with our values for the color-temperature of the screen light gives interesting information on the changes in color produced by the optical systems of the particular projector lamps used. With the low-intensity lamp and the condenser-type high-intensity lamp the color-temperatures of the light on the screen show relatively small departure from that obtained on the bare sources. The low-intensity shows a little higher color-temperature for the light on the screen compared to the bare source, and the condenser-type high-intensity lamp shows slightly lower color-temperatures on the screen. With the 7-mm and 8-mm Suprex positive carbons the color-temperature of the bare source ranged from 5800° to 6400°K. These light-sources show a color-temperature through the optical system on the screen 800° to 900° lower than the bare sources. This behavior brings the color-temperature of the light on the screen and its spectral-energy distribution into closer agreement with that obtained from the condenser-type lamp and results in a narrow spread of color between all our high-intensity arcs.

There are other factors which can affect the spectral-energy distribution and color-temperature of the light on the projection screen. We have made some preliminary studies of the effect of different lenses and mirrors, and believe that their effect in general will be small. As mentioned above, the position of the carbon with respect to the optical system can influence the color. Increase of carbon distance from the mirror in general causes an increase in color-temperature, although from exploratory measurements this change was of the same order of magnitude as the differences between the various high-

intensity combinations shown in Table I. While these minor variations in color-temperature of the screen light from the various high-intensity projector lamp and carbon combinations could probably be discerned by simultaneous comparison side by side, the differences are small in comparison with the familiar difference in color of screen light from the low-intensity and high-intensity lamps.

If subsequent developments, especially in the art and technology of colored motion pictures, indicate the desirability of alterations in the color-temperature of some of these high-intensity lamps, this can to some extent be carried out. Changes in color-temperature can be produced by alteration of the carbon, which has been done for some applications in the past.[12, 13]

The results described in this paper give us assurance that with equipment in good condition and properly adjusted, the popular high-intensity lamp and carbon combinations give remarkably consistent color and spectral-energy distribution. We plan to extend these measurements to a study of the variations in color that may be produced when the lamps and carbons are not maintained in optimal adjustment.

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NEW 13.6-MM CARBONS FOR INCREASED SCREEN LIGHT*

M. T. JONES, W. W. LOZIER AND D. B. JOY**

Summary.—*A new 13.6-mm super high-intensity carbon designed for 170-ampere operation gives a substantial increase in light over either the old 180-ampere 13.6-mm super carbon or the 125 to 150-ampere new regular 13.6-mm carbon described previously.*[6] *The new regular and super carbons are compared with the old carbons as to light available on the screen and as to efficiency of light production.*

During the past several years there have been two types of 13.6-mm carbons available for use in the condenser type of lamp with a rotating positive carbon—the so-called regular carbon ordinarily burned at 125 amperes, and the super carbon burned at 180 amperes.[1, 2] However, the larger motion picture screens could not be lighted to adequate brightness with these carbons and the available optical systems. Recent improvements in carbons and optical systems have radically increased the obtainable screen light intensities. This paper describes a new carbon designed to yield a higher amount of screen light than it is possible to obtain from the other standard projector carbons, and discusses its possibilities for the illumination of large screens.

Employing $f/2.2$ condensers and an $f/2.0$ projection lens having treated surfaces,[3] the 13.6-mm regular carbon at 125 amperes gave approximately 11,500 lumens on the screen with 80 per cent side-to-center distribution and with the shutter not running. With a 90-degree projector shutter and a screen 30 feet in width this would amount to about 10 foot-candles in the center of the screen. For a flat white screen in good condition this is equivalent to a brightness of about 7.5 foot-lamberts, a figure which is below the recommended limits[4] of $10 \pm \frac{4}{1}$. For these theaters there was available the 13.6-mm super carbon at 180 amperes which gave 30 per cent more light and would therefore increase the foot-candle reading to 13 and the brightness to 10 foot-lamberts at the center of the 30-ft screen. The fact

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** National Carbon Company, Fostoria, Ohio.

that this super carbon burns at 25 inches per hour compared to 13 for the regular, and requires 180 amperes instead of 125, limits its application although it has been adopted by a number of the larger theaters and also has been used successfully for rear projection in the motion picture studios.[5] It has been possible to improve this situation, as described last Spring,[6] through the development of a carbon which gives slightly higher light at 150 amperes than the super at 180 amperes but with a burning rate of only 15 inches per hour instead of 25. It can also be burned at as low a current as 125 amperes and at this current gives the same light as the above-mentioned regular carbon but at a 35 per cent lower consumption rate. This has there-

TABLE I

Characteristics of 13.6-Mm H. I. and Super H. I. Projector Carbons under Typical Operating Conditions

Carbon	Old Regular H. I. Projector	Old Super H. I. Projector	New Regular* H. I. Projector[6]	New Super H. I. Projector
Arc amperes	125	180	150	170
Arc volts	68	75	78	75
Positive consumption rate (inches per hour)	13	25	15	22
Crater candlepower	43,000	60,000	63,000	78,000
Screen lumens without film shutter*	11,500	15,000	16,000	18,500

* At 80 per cent side-to-center distribution ratio with $f/2.2$ condenser system and 5-inch $f/2.0$ treated Super Cinephor projection lens.

fore brought a center brightness of 10 foot-lamberts on a 30-ft flat white screen within the reach of many theaters which, because of either the high-carbon consumption or the high-arc current, hesitated to adopt the 180-ampere super carbon.

However, there is an appreciable number of large theaters which have screens of 30 feet or wider where the desire is not for a carbon which will give the same light at a lower current or lower consumption, but for a carbon which will give more light and still be acceptable in respect to current usage and carbon consumption. We have recently been able to develop such a carbon. This is known as the new super carbon; it can be burned up to 170 amperes, where it has a consumption of 22 inches per hour and, with the same optical system described above, it gives at least 20 per cent more light on the projection screen than the 180-ampere super carbon. This makes

available 18,500 lumens without film or shutter, and results in approximately 16 foot-candles or 12 foot-lamberts at the center of a 30-ft screen, thereby approaching more nearly to the illumination desired by these large theaters. With optical systems using slightly

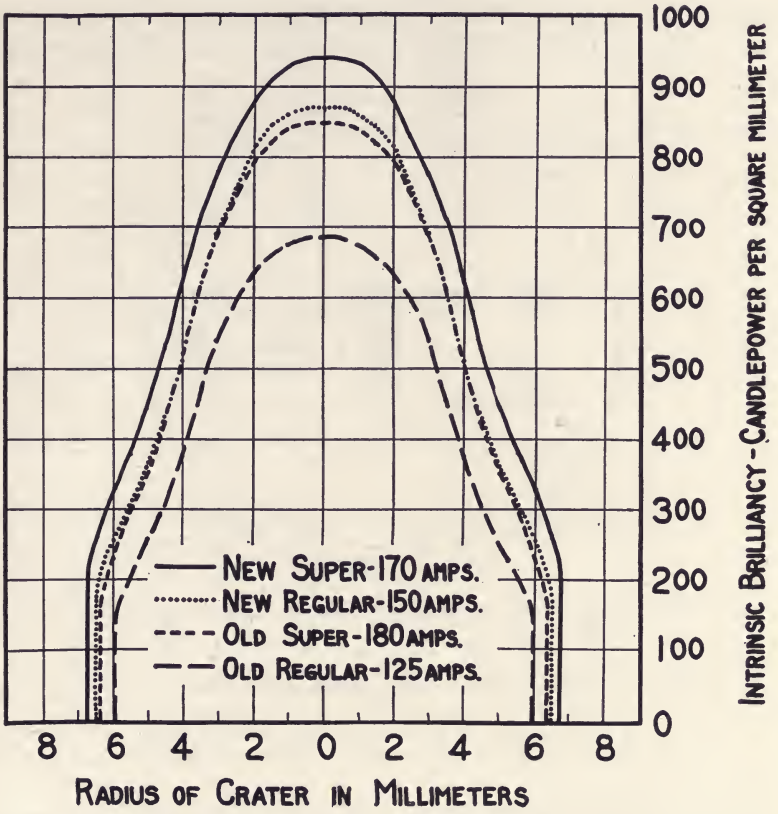

FIG. 1(*a*). Intrinsic brilliancy distribution across crater of 13.6-mm H. I. carbons.

slower condensers and objective lenses, the increase in screen light with this new super carbon is in some cases as much as 35 per cent over that of the old super carbon.

The color of the light on the projection screen is the same with the new super carbon as with the old. The light passing through the aperture, however, has less heating effect per unit of light. Using the same optical system with which the new super carbon gave 20

per cent more light than the old, measurements indicate only about 5 per cent increase in total energy passing through the film aperture.

A comparison of carbon consumption rate, current, arc voltage, and screen light for the four above-mentioned carbons is summarized in Table I. The increase in light with the new carbon is due to the higher and broader intrinsic brilliancy curve as indicated in Fig. 1(*a*). This intrinsic brilliancy curve shows the amount of light

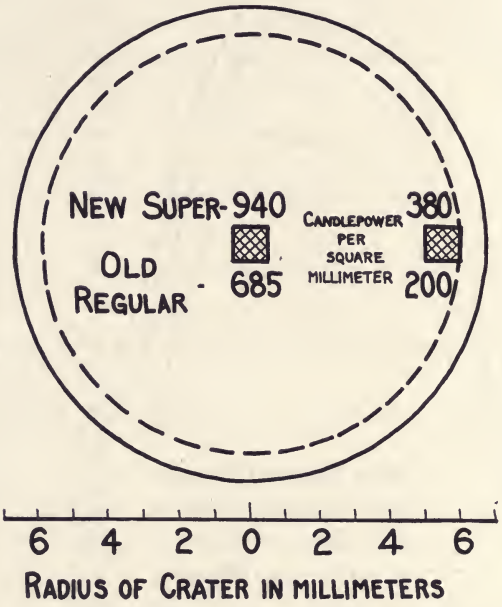

FIG. 1(*b*). Diagram of crater opening of 13.6-mm old regular and new super H. I. carbons showing brilliancy at center and near edge of crater.

emitted in the forward direction per unit area across the crater. For example, assume we are looking directly into the crater as shown in Fig. 1(*b*). From each sq-mm (about the size of the head of a common pin) of area at the center of the crater of the new super carbon, the amount of light coming toward us would be equivalent to that from 940 candles. At this same point on the old type regular carbon we would have the lower intensity of 685 candles. Similarly, near the side of the crater the brilliancy would be 380 candles per sq-mm for the new super and 200 for the old regular carbon. For a given optical system, *i. e.*, condensers and objective lens, the light

on the screen, as shown by Cook,[7] should be governed by the intrinsic brilliancy of the carbon plus, to some extent, the width of the high-brilliancy usable portion of the crater. It is thus apparent why the available lumens on the screen for a given optical system and

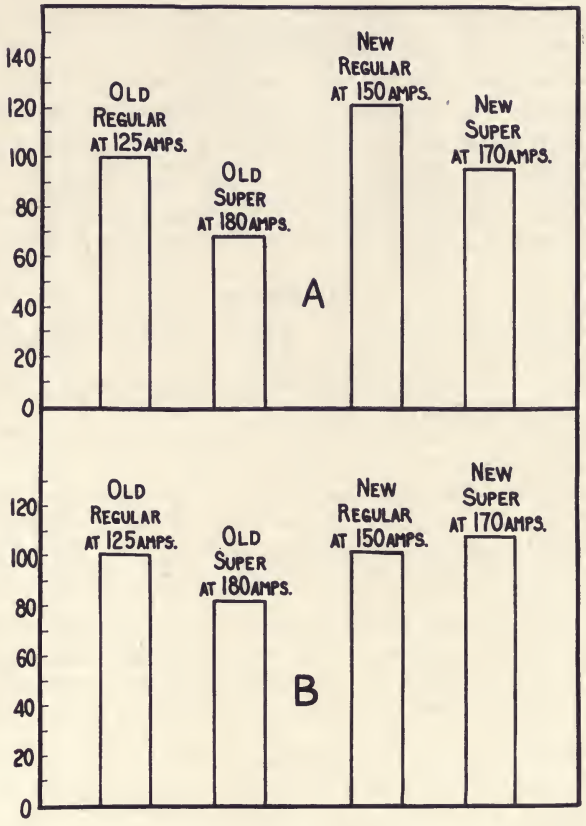

FIG. 2. Relative quantity of screen light: (*A*) per inch of carbon; (*B*) per arc kilowatt-hour.

screen distribution are highest for the new super, somewhat lower for the old super and new regular, and still lower for the old regular.

Another way of comparing these carbons is by a previously described method[8,9] of indicating the quantity of screen light produced per unit of carbon and electrical energy consumed. Such a comparison is given in Fig. 2. The old super carbon achieves higher screen

light than the old regular at the expense of a 32 per cent decrease in quantity of light per inch of carbon consumed and an 18 per cent decrease in light per arc kilowatt-hour. The new regular carbon at 150 amperes with slightly higher light than the old super at 180 amperes gives approximately 75 per cent more light than the old super for each inch of carbon consumed and is, in fact, about 20 per cent better in this respect than the old regular. The new super with its 20 per cent increase in light over the old super is 40 per cent superior to the old super in quantity of light produced per inch of carbon. Even with its higher light output, the new super produces more light per arc kilowatt-hour than do any of the other carbons. This new super carbon therefore supplies a desirable increase in screen light with improved efficiency of utilization of carbon and power.

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THE CONSUMPTION OF THE POSITIVE ARC CARBON*

H. G. MacPHERSON**

Summary.—*The consumption of the positive electrode of an arc between solid carbons in air results partly from evaporation and partly from oxidation. The oxidation is operative chiefly on the sides of the carbon, tapering the end of the electrode and thus producing a tip with a diameter $^1/_2$ to $^5/_8$ that of the original carbon. The consumption of the flat tip, or crater, however, is due almost entirely to evaporation. The evaporation rate is controlled by the pressure of carbon vapor at the crater surface and the mechanism of diffusion away from it. This diffusion was computed on the assumption that it is similar to that occurring in the evaporation from liquid drops of the same diameter as that of the carbon crater, and it was shown that the linear electrode consumption should be inversely proportional to the crater diameter. This was borne out approximately by measurements of consumption rates made near the overload current. The absolute values of the consumption rates are consistent with the hypothesis that the surface temperature of the positive crater is at or near the sublimation temperature of carbon.*

In an arc between pure carbon electrodes the crater face of the positive carbon has a remarkably uniform temperature when the arc current is at its maximum for peaceful operation of the arc. This temperature is independent of the size of the positive electrode and can be reproduced at will. The constancy of this temperature has led to the belief that the positive crater of the arc operates at the sublimation temperature of carbon. In an effort to gain some light on this question, an attempt has been made to calculate theoretically the consumption rate of the positive carbon and compare this calculation with measurements.

Fig. 1 is a picture of an arc between solid carbon electrodes. In this case the lower carbon is the positive electrode and is 7 mm in diameter. The upper electrode is 5 mm in diameter and the arc current is about 12 amperes. The negative carbon tapers to a rounded point and is consumed and shaped to this form largely by oxidation of carbon from its sides in combination with some evaporation from the tip. The positive carbon is tapered somewhat on the

* Received February. 2, 1942.

** National Carbon Company, Cleveland, Ohio.

sides by oxidation, but there is a flat tip or crater that is consumed almost entirely by evaporation.

The calculation of the consumption rate of the positive carbon was made on the theory that the rate of evaporation from the tip is controlled by the vapor pressure of carbon at the temperature of the crater and the laws of ordinary gaseous diffusion away from the crater. The diffusion was computed on the assumption that it is similar to that occurring in the evaporation from liquid drops of the same diameter as the carbon crater. The diffusion is then radial with spherical symmetry, and it was assumed that the diffusion takes place into one hemisphere only. The consumption of the positive carbon as calculated in this way is proportional to

FIG. 1. Arc between small solid carbons.

$$\frac{DMp}{RdT} \qquad (1)$$

where D is the diffusion constant of the vapor at the arc temperature, M is the molecular weight of the diffusing gas, p is the vapor pressure of carbon at the crater surface, R is the radius of the crater tip, d is the density of the carbon in the electrode, and T is the effective temperature of the gas through which the diffusion takes place.

Some difficulty was encountered in obtaining a value for the diffusion constant of carbon vapor used in this equation. The diffusion constants of various gases into air as given in the International Critical Tables were plotted as a function of molecular weight on logarithmic paper and it was found that a fairly good straight line was obtained with a slope indicating that the diffusion constant varies inversely as the square-root of the molecular weight of the gas, as is, of course, predicted by kinetic theory. Thus a diffusion constant could be picked off from this curve for carbon vapor at room temperature. According to kinetic theory, the diffusion constant should vary as the three-halves power of the temperature. Experimentally, however,

measurements near room temperature have shown that D varies as a higher power of the temperature, up to T^2. This greater variation of diffusion with temperature is associated with a change in the collision cross-section of the atoms and probably does not extend to higher temperatures. Therefore it was thought most satisfactory simply to multiply the diffusion constant for room temperature by a factor of 1.35 and use the predicted kinetic theory variation of diffusion constant with temperature. This factor of 1.35 was obtained from a

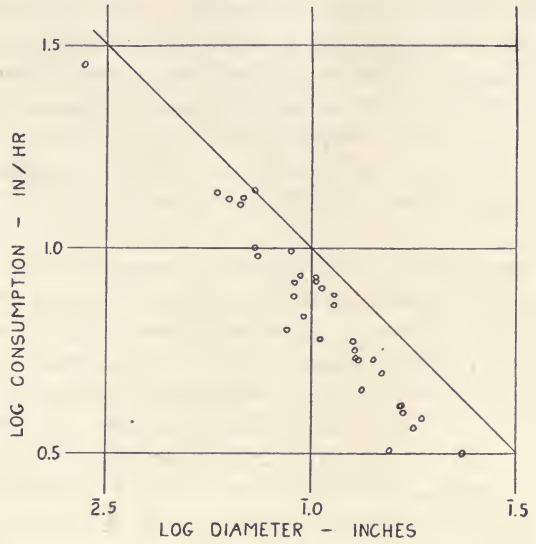

FIG. 2. Carbon consumption, calculated and measured.

Sutherland equation for the dependence of the viscosity on the temperature, based on viscosity measurements on nitrogen up to 1000°K.

Substituting the value thus obtained for the diffusion coefficient, the linear consumption of the carbon electrodes in inches per hour is

$$C = 0.0038 \frac{\sqrt{MT}}{Rd} p \qquad (2)$$

The symbols have the same meaning as above. p is expressed in atmospheres, T is in °K, R is in inches, and d is the density ingrams per cubic-centimeter. A numerical calculation of the consumption was made, assuming a molecular weight of 12, a temperature of

3950°K, a density of 1.62 corresponding to graphite electrodes, and a vapor pressure of carbon of one atmosphere. This calculation is plotted as the diagonal straight line of Fig. 2. Also shown in Fig. 2 are measurements made on a large number of arcs using positive carbons with original diameters of $^1/_{16}$ to $^3/_8$ inch. Some of the points represent arcs in which the positive carbon was used as the lower electrode and others in which the positive was the upper electrode, and both amorphous carbon and graphite electrodes are represented. The arcs were run at a current just below overload, and the consumption and final crater diameter measured. The consumption rates varied from about 3 to 28 inches per hour in the range of carbons used. The measurements confirm the prediction that the consumption rate should vary inversely as the crater diameter. The actual consumptions found are on the average about 30 per cent lower than those calculated. This must be considered a fortuitously close fit, considering the approximate measurements and the uncertainty in the calculations.

These uncertainties in the calculations should be pointed out. In the first place, it is assumed that the carbon burns with a hemispherical tip instead of a flat tip. This assumption would lead to a high value for the calculated consumption. It was further assumed that the carbon vapor diffuses only throughout one hemisphere instead of in all directions. This probably tends to produce too low a value for the calculated consumption, although the carbon oxidized and evaporated from the tapered sides will prevent downward diffusion to some extent. Furthermore, the extrapolation of the diffusion constant to a new gas at an extremely high temperature is somewhat uncertain. The temperature of the gas in which the diffusion takes place is not uniform, but is higher than the assumed value within the arc stream and is lower than this value at some distance to the sides of the arc. In view of these approximations in the calculations, absolute agreement with experiment is not expected to be close, and therefore we can not hope to get an accurate value for the vapor pressure of carbon at the temperature of the crater surface from these data. However, the trend of the data indicates the correctness of our viewpoint that the loss of evaporated carbon is determined by a process of ordinary gaseous diffusion through a non-turbulent gas. Furthermore, the absolute agreement is such that it is probable that the vapor pressure of carbon at the temperature of the crater surface lies between four-tenths of an atmosphere and one atmosphere.

If we assume that, at the maximum crater temperature, the vapor pressure of carbon is one atmosphere, then a simple theory of overloading of such an arc can be outlined. So long as the vapor pressure of carbon at the surface is equal to or less than atmospheric pressure, then a smooth streamline flow of gas around the positive carbon will be obtained and the carbon vapor will leave the crater surface by diffusion through this gas. However, if the current is raised to such a point that this sublimation temperature of carbon is exceeded at points on the crater, the excess pressure of carbon vapor developed will produce spurts of gas away from the crater face and cause a turbulence. The turbulent flow will allow fresh air with a low concentration of carbon vapor to come close to the crater face and this will result in such a high concentrational gradient that the diffusion and evaporation of carbon from this part of the crater face will be extremely rapid. The rapid evaporation will, of course, cool the spot on the crater very rapidly, restoring that part of the crater to normal operation. At overload currents this process goes on repeatedly, resulting in an unstable arc and in a sputtering or hissing noise. Just below this current, however, smooth operation is obtained, corresponding to streamlined flow and steady diffusion of carbon vapor.

STABILIZED FEEDBACK LIGHT-VALVE*

W. J. ALBERSHEIM AND L. F. BROWN**

Summary.—*Feedback affords controlled and undistorted damping of light-valve resonance. All electromechanical devices can be regarded as feedback circuits if their motional impedance is interpreted as a feedback counter-emf. Auxiliary amplification of this counter-emf produces stabilized motional feedback. Depending on whether the amplifier counter-emf is proportional to amplitude, velocity, or acceleration, the feedback tends to flatten amplitude, velocity, or acceleration response characteristic. The light-valve is a mechanically resonant device operated on an amplitude basis but with a velocity counter-emf. Velocity feedback increases the effective damping of the light-valves; reactive components in the electrical driving impedance and in the feedback-gain tend to shift the resonance frequency. At 0.71 of critical damping the steady-state frequency characteristic is peakless and the valve follows transient impulses quickly with only 6 per cent overshooting. The maximum "bucking power" opposed to the valve motion by the feedback amplifier occurs at 0.58 of ribbon resonance and is 8 db less than the low-frequency power of the driving amplifier.*

An amplifier is described that has been designed in accordance with the theory for application of stabilized feedback to commercial light-valves.

The feedback light-valve was developed in order to obtain controlled damping of mechanical resonance without the distortion and temperature variations inherent in mechanical damping methods.

The application of stabilized feedback to light-valves is a special case of the well known negative feedback in transmission systems.[1] Fig. 1 shows schematically two forms of electrical feedback. In Fig. 1(*a*) the feedback-emf is obtained from the output voltage of the stabilized amplifier. It becomes inoperative if the output voltage is short-circuited by the switch indicated in the drawing. In Fig. 1(*b*) the feedback-emf is obtained from the output current of the amplifier so that it becomes inoperative if the output current is interrupted by the switch *SW*. The gain of such feedback amplifiers is computed by equations *3* and *6* in the appendix to this paper. They are alike in

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form although the physical meanings of the symbols μ and β in the two equations are different.

In both cases, the polarity of the feedback is such that it reduces the amplifier gain. If the overall feedback gain $\mu\beta$ is much larger than one, the output tends to become independent of μ and is deter-

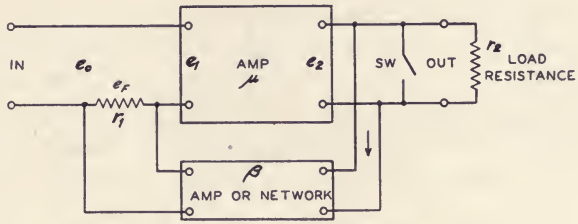

FIG. 1 (*a*). Feedback from output voltage.

mined by the loss β in the feedback network as shown by equations 3*b* and 6*b*. Since amplifier gains vary with battery voltages, tube characteristics, and frequency, whereas the feedback circuit can be a passive network with a constant and predetermined loss characteristic, the amplifier is "stabilized" by reducing the influence of μ.

Consider now an electromechanical device of arbitrary nature such as shown in Fig. 2. The input voltage E_0 produces a motion of

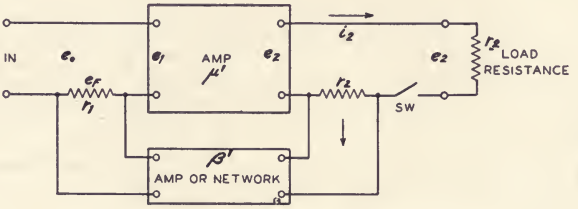

FIG. 1 (*b*). Feedback from output current.

velocity V in the armature. Since the device is built for the sake of this mechanical motion, one can regard its velocity as the "output," and as corresponding to the output current of the electrical amplifier shown in Fig. 1(*b*). If the device is of an electromagnetic or electrodynamic nature, the motion of the armature will produce in the electrical input circuit a counter-emf proportional to the armature velocity. This counter-emf disappears when the armature is clamped, just as the feedback-emf in Fig. 1(*b*) disappears if the output current is

interrupted. Formally, the electromechanical device corresponds exactly to the current-type feedback amplifier of Fig. 1(*b*). In accordance with this analogy, the mathematical formula for the output velocity (equation *12*) shows the same structure as equation *6*. The stabilizing effect of the electromechanical reaction is well known and

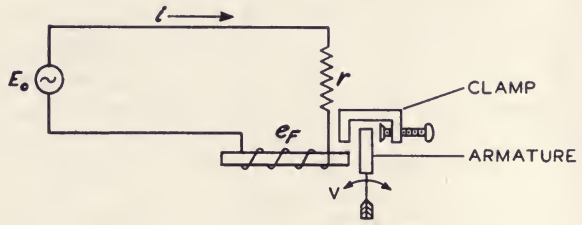

FIG. 2. Electromechanical device.

utilized for the damping of electrical meters and other devices. It is usually, however, not interpreted as a feedback or counter-emf but as motional impedance.

In order to enhance the effect of this reaction, one may pick up a part of the motional counter-emf, boost it in an auxiliary amplifier, and feed it back into the electrical input circuit.[2] This leaves the form of the equations unchanged but it increases the magnitude of the

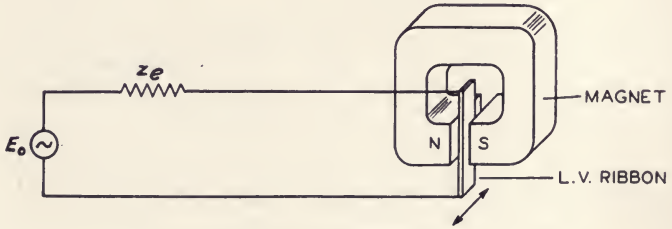

FIG. 3. Light-valve.

feedback-constant so that one can obtain greatly increased stabilization. If the feedback input voltage is picked up electromagnetically or electrodynamically, it is proportional to the armature velocity and therefore tends to produce a constant-velocity characteristic. If the feedback pick-up is electrostatic, it depends upon the position of the armature and therefore tends to produce constant-amplitude characteristics. If the feedback pick-up generates voltage by pressure, it will tend to flatten the acceleration characteristic of the device.

The general results given above are directly applicable to the ribbon light-valve used in sound-film recording. The light-valve is, in principle, a very simple device, as shown by Fig. 3. It consists merely of one or several tightly stretched metal ribbons placed in a magnetic field. Mechanically the light-valve ribbon is a resonant structure, with extremely small damping, so that if one eliminates the effect of its motional counter-emf by driving it at constant current (that is, infinite input impedance), its response shows a very sharp and high peak. The velocity-response for this condition is given by equation *17*. Since the use of the light-valve depends upon amplitude rather than velocity, its performance can be more readily analyzed from its amplitude characteristic, which is given by equation *18*. If the valve

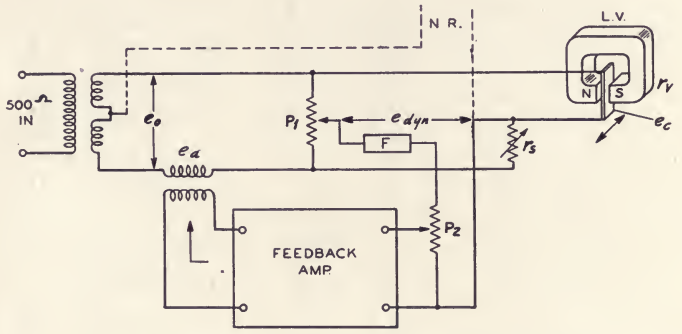

FIG. 4. Schematic circuit of feedback light-valve.

is operated from a finite electrical input impedance, its velocity and amplitude responses are given by equations *19* and *20*, which differ from the previous equations by the addition of an electrodynamic damping term proportional to the square of the magnetic field strength and to the electrical conductivity. By very careful design it has been possible in recent light-valves to lower the amplitude peak from the 40 db corresponding to mechanical friction to less than 10 db. In most light-valves now in commercial use, however, the resonance peak approximates 20 db. Such a peak is undesirable, due not only to the steady-state frequency distortion but because it increases the danger of overload, and produces free vibrations at the ribbon's resonance-frequency when the valve is excited by a transient impulse. It was therefore decided some years ago to improve the light-valve characteristic by the application of stabilized feedback. The type of

circuit adopted is schematically shown in Fig. 4.[3] The problem of obtaining a pick-up voltage proportional to the ribbon motion, without changing the internal structure of the light-valve, was solved by means of a bridge circuit consisting of potentiometer P_1, light-valve ribbon resistance r_V, and the "simplex" resistance r_s. This bridge is electrically balanced so long as the ribbons are prevented from moving (by clamping or by removal of the magnetic field). Under operating conditions, the voltage across the bridge is directly proportional to the ribbon velocity. It is boosted in the auxiliary amplifier and fed back into a low-impedance transformer winding in series with the main driving transformer. Since the voltage pick-up is proportional to

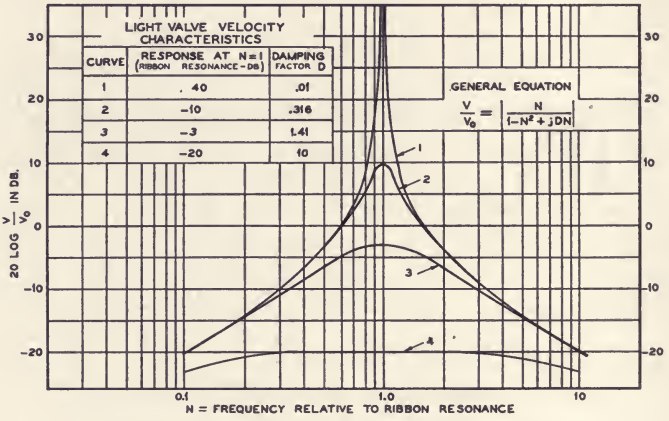

FIG. 5. Light-valve velocity characteristic.

velocity, one might expect that the feedback would produce a constant-velocity light-valve. This can actually be obtained, as shown by the velocity characteristic of Fig. 5, curve *4*, but only at impractically high feedback values and with great loss in efficiency over the entire working range. Fortunately a much smaller amount of feedback is sufficient to produce a smooth amplitude characteristic at frequencies below the ribbon resonance. This is indicated by the amplitude characteristics of Fig. 6. By a moderate amount of feedback, the damping factor can be made equal to 0.71 of the critical damping. At this damping the resonance peak is completely eliminated and transformed into a smooth low-pass filter characteristic which droops 3 db at the ribbon's resonance frequency, and at higher frequencies produces a loss of 12 db per octave (Fig. 6, curve *3*). The

transition from flat to drooping response is so gradual that it can easily be compensated by equalization, and the working range extended to frequencies well above light-valve resonance.

Fig. 7 shows the transient responses corresponding to the steady-state velocity and amplitude characteristics, shown in Figs. 5 and 6. Curves *1* (Fig. 7) show the response of a light-valve damped only by mechanical friction. It is seen that a sudden impulse produces a weakly damped free oscillation which requires hundreds of vibrations before it dies down to imperceptible levels. Curves *2* correspond to a 10-db amplitude peak, drawn on a much wider scale because the free

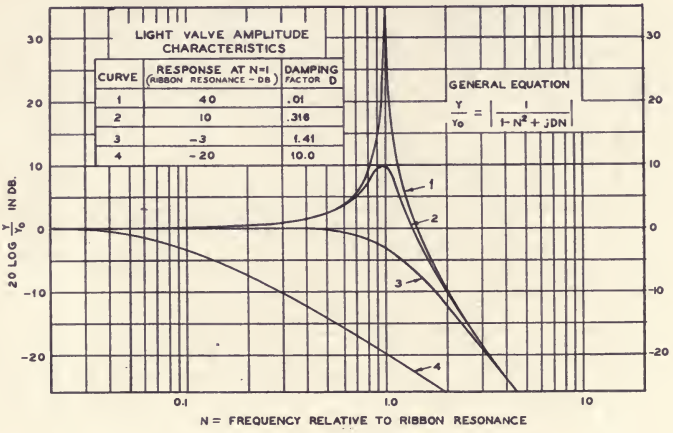

FIG. 6. Light-valve amplitude characteristics.

vibrations caused by a transient impulse die down after two or three cycles. Curve *3* corresponds to 0.71 of critical damping, which produces a peakless, smooth, steady-state amplitude characteristic. The transient response overshoots its final position by only about 6 per cent and the transient dies down after a time, corresponding to one vibration of the undamped ribbon. Curve *4* is drawn for a feedback five times as large as critical damping. This produces not only a loss in efficiency and a drooping amplitude characteristic but also a very sluggish aperiodic response to transient impulses.

The curves in Figs. 5, 6, and 7 are computed from equation *25*, *26*, and *31*. These equations are strictly correct only if the electrical input to the light-valve is a pure resistance and the feedback amplifier gain is constant and accordingly free from phase distortion at all fre-

quencies. If the electrical input or the feedback-gain contain reactive components, the result will be a modification of the damping and a change in the resonance frequency of the light-valve. Under practical conditions it is neither possible nor desirable to obtain completely flat feedback-gain characteristics. The feedback amplifier needs to be efficient only in a frequency-band near the ribbon resonance. At low

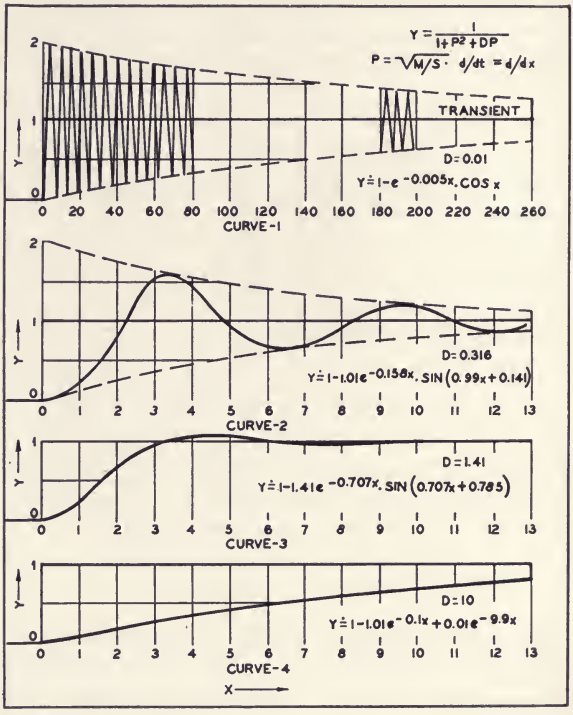

FIG. 7. Light-valve transients.

frequencies its gain is greatly reduced in order to prevent feedback of noise-reduction bias currents; at high frequencies its gain droops to avoid singing at mechanical harmonics of the ribbon resonance frequency. In the working range its phase characteristic is such that it tends to raise rather than lower the resonance frequency of the light-valve and to produce an even flatter response than indicated by the elementary theory.

The main effect of stabilized feedback from a steady-state point of view is a reduction of ribbon amplitude near resonance. The feedback amplifier must therefore supply some electrical power opposing or "bucking" the power supplied by the driving amplifier. This bucking power is much smaller than the main driving power because at low frequencies the required input correction is small, and at resonance, where nearly the entire driving voltage must be bucked out, the current taken by the valve is negligible. As shown in the appendix, a maximum of 8 db less than the power of the driving power is required. Since this maximum occurs at high frequency (0.58 of

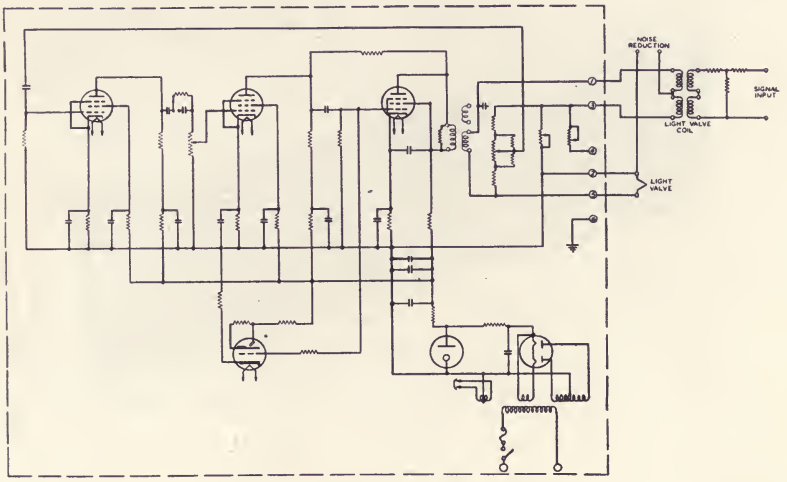

FIG. 8. *RA-1111-A* amplifier.

ribbon resonance), all harmonics of the feedback-emf fall beyond the transmission band of the reproducing circuits. The power requirements of the feedback amplifier are therefore not severe.

The ERPI *RA-1111-A* amplifier has been designed in accordance with the foregoing theory for the application of stabilized feedback to the *RA-1061* light-valve as well as certain other ERPI light-valves. The schematic circuit of the amplifier is shown in Fig. 8. This device, of which Fig. 9 is a photograph, is contained in a dish-type, $5^1/_4$-in. rack-mounting panel. The vacuum-tube heater and plate voltage are provided by a self-contained, regulated power unit which enables the amplifier to operate from 115-v, 50 to 60-cycle alternating current.

The bridge-balancing potentiometer and electronic "eye" and amplifier gain control are accessible through a door in the front mat. Balancing is accomplished by adjusting the electronic "eye" for minimum deflection with a 400-cycle sine-wave signal impressed on the input of the light-valve transformer. For this adjustment, the first two stages of the amplifier and the electronic "eye" act as the "galvanometer" in the bridge circuit. After this adjustment has been made, the gain of the amplifier is adjusted to give the same light-valve response or ribbon amplitude at 400 and 8000 cycles for equal levels at the light-valve transformer input. This may be done by a

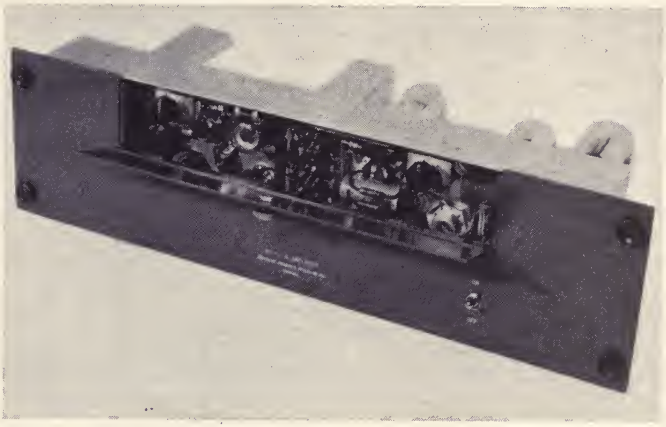

FIG. 9. *RA-1111-A* amplifier.

stroboscopic method or by the use of a calibrated photoelectric cell monitor. The design of the amplifier circuit is such that this adjustment will result in uniform light-valve response from 40 to 8000 cycles for light-valves tuned to 10,000 cycles. The response decreases sharply above 10,000 cycles.

Thus the use of a multisection low-pass filter is unnecessary with the stabilized feedback light-valve, and the transient distortions of the resonant circuits of the filter and the mechanical resonance of the light-valve are eliminated. The elimination of these distortions is easily demonstrated by the use of square-wave signals, and indeed square-wave signals are used in the production adjustment and testing of the amplifiers. The effect upon the ear of the removal of these distortions is not readily correlated with other distortion effects, and

has been described as resulting in a "more solid bass" and a "decrease in response in the 300-cycle region," which leads to the conclusion that the undesirable effects of the transient high-frequency distortions lie in the generation of intermodulation products by the high-frequency oscillations excited by impact signals in undamped circuits.

The *RA-1111-A* amplifier may also be used to apply stabilized feedback to push-pull light-valves. For this use the counter-emf from two ribbons of the valve is amplified and fed back to all four ribbons. The motional impedances of the various ribbons are sufficiently uniform to make this practicable.

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[1] BLACK, H. S.: "Wave Translation System"; U. S. Patent 2,102,671.

[2] MAXFIELD, J. P., AND HARRISON, H. C.: "Vibratory System"; U. S. Patent 1,535,538.

[3] ALBERSHEIM, W. J., AND SETTE, W. J.: "Recording System"; U. S. Patent 2,157,880.

APPENDIX

(1) ELECTRICAL FEEDBACK CIRCUITS

(*1.1*) *Feedback from Output Voltage.*

Source voltage $= e_0$
Feedback voltage $= e_f$
Amplifier input voltage $= e_1$
Amplifier output voltage $= e_2$
Amplifier gain $= \mu$
Feedback gain $\left(\frac{e_f}{e_2}\right) = \beta$

$$e_1 = e_0 - e_f = e_0 - \beta e_2 = e_0 - \mu\beta e_1 \qquad (1)$$

$$e_1 = \frac{e_0}{1 + \mu\beta} \qquad (2)$$

$$e_2 = e_0 \frac{\mu}{1 + \mu\beta} \qquad (3)$$

$$\text{for } \mu\beta \gg 1,\ e_2 \doteq \frac{e_0}{\beta} \qquad (3b)$$

(*1.2*) *Feedback from Output Current.*

Source voltage $= e_0$
Feedback voltage $= e_f$
Amplifier input voltage $= e_1$
Amplifier output current $= i_2$
Amplifier transconductance $\left(\frac{i_2}{e_1}\right) = \mu'$

$$\text{Feedback impedance}\left(\frac{e_f}{i_2}\right) = \beta'$$

$$e_1 = e_0 - e_f = e_0 - \beta' i_2 = e_0 - \mu'\beta' e_1 \tag{4}$$

$$e_1 = \frac{e_0}{1 + \mu'\beta'} \tag{5}$$

$$i_2 = e_0 \frac{\mu'}{1 + \mu'\beta'} \tag{6}$$

$$\text{for } \mu'\beta' \gg 1,\ e_2 \doteq \frac{e_0}{\beta'} \tag{6b}$$

(2) ELECTROMECHANICAL DEVICES

(2.1) *Analogy of Electromechanical Device and Current Type Feedback Circuit.*

Mechanical force	$= F$
Velocity	$= v$
Mechanical impedance	$= Z_m$
Electrical impedance	$= z_e$
Electrical input current	$= i$
Electrical input voltage	$= e_0$
Electromechanical counter-emf	$= e_c$
Force factor	$= A$

$$F = Ai \tag{7}$$

$$i = (e_0 - e_c)/z_e \tag{8}$$

$$v = \frac{F}{Z_m} = \frac{Ai}{Z_m} \tag{9}$$

$$v = \frac{(e_0 - e_c)A}{Z_m z_e} \tag{10}$$

$$e_c = vA \tag{11}$$

$$v = \frac{(e_0 - vA)A}{Z_m z_e} = e_0 \frac{A/Z_m z_e}{1 + \dfrac{A^2}{Z_m} z_e} = e_0 \frac{\mu''}{1 + \mu''\beta''} \tag{12}$$

with

$$\mu'' = \frac{A}{Z_m} z_e \tag{13}$$

$$\beta'' = A \tag{14}$$

(2.2) *Application of Stabilized Feedback to Electromechanical Devices.*—Assume that by auxiliary amplification the dynamic counter-emf is boosted to

$$e_f = e_c(1 + b) = vA(1 + b) \tag{15}$$

Then,

$$v = \frac{[e_0 - (1+b)vA]A}{Z_m z_e} = \frac{e_0 \frac{A}{Z_m} z_e}{1 + (1+b)A \frac{2}{Z_m} z_e} = e_0 \frac{\mu''}{1 + \mu'' \beta'''} \qquad (16)$$

in which β''' is increased to

$$\beta''' = (1+b)A \qquad (16b)$$

(3) LIGHT-VALVE RESPONSE

Electrical impedance of valve plus driving circuit	$= z_e$
Magnetic field strength	$= B$
Effective valve ribbon length	$= L$
Effective flux BL (force factor)	$= A$
*Effective ribbon stiffness	$= S$
*Effective ribbon mechanical resistance	$= R$
*Effective ribbon mass	$= M$

(*3.1*) *Constant-Current Input* (*Infinite Driving Impedance*).

Velocity:
$$v = i \frac{A}{Z_m} = i \frac{A}{\frac{S}{jw} + Mjw + R} \qquad (17)$$

Amplitude:
$$y = \frac{v}{jw} = i \frac{A}{S - Mw^2 + Rjw} \qquad (18)$$

This is sharply resonant at the frequency $\sqrt{M/S}$ because the mechanical friction resistance is so small that a peak of 40 db may occur.

(*3.2*) *Voltage Type Input.*—With a finite driving impedance (preferably lower than the ribbon resistance) one finds immediately from *12:*

$$v = \frac{e_0 \frac{A}{z_e}}{Z_m + \frac{A^2}{z_e}} = \frac{e_0 \frac{A^2}{z_e}}{\frac{S}{jw} + Mjw + R + \frac{A^2}{z_e}} \qquad (19)$$

$$y = \frac{v}{jw} = \frac{e_0 \frac{A}{z_e}}{S - Mw^2 + jwR + \frac{A^2}{z_e}} \qquad (20)$$

(4) FEEDBACK LIGHT-VALVE (FIG. 4)

Assume that the impedances of the bridging potentiometer P_1, filter network F, and gain-control potentiometer P_2 are high compared to the light-valve and driving-circuit impedances. The bridge circuit is electrically balanced so that e_{dyn} is zero as long as the ribbons do not move ($B = 0$).

---

* *Note:* Effective stiffness, mechanical resistance, and mass are defined as the total force distributed over the effective ribbon length required to obtain at the center of the light-valve ribbon a unit of amplitude, velocity, and acceleration, respectively.

When the ribbons move, e_{dyn} is proportional to their velocity, and for a symmetrical bridge ($r_s = r_v$) and very high impedance F or P_2, it approaches half the dynamic counter-emf of the light-valve:

$$e_{dyn} = 0.5e_c \tag{21}$$

The amplified counter-emf fed back into the driving circuit is

$$e_a = be_c \tag{22}$$

where b is the product of network losses and amplifier gain. The total effective feedback voltage becomes

$$e_f = e_c + e_a = (1 + b)e_c \tag{15}$$

Introducing this value into *12*,

$$v = e_0 \frac{\frac{A}{Z_m} z_e}{1 + (1 + b)\frac{A^2}{Z_m} z_e} \tag{16}$$

$$v = \frac{e_0 \frac{A}{Z_c}}{\frac{S}{jw} + Mjw + R + (1 + b)\frac{A^2}{z_c}} \tag{23}$$

$$y = \frac{e_0 \frac{A}{z_e}}{S - Mw^2 + \left[R + (1 + b)\frac{A^2}{z_e}\right]jw} \tag{24}$$

If z_e approximates a pure resistance r, and b a constant numerical gain without reactive components, equations *23* and *24* can be simplified and normalized:

$$v = v_0 \frac{N}{1 - N^2 + jDN} \quad \text{(Fig. 5)} \tag{25}$$

$$y = y_0 \frac{1}{1 - N^2 + jDN} \quad \text{(Fig. 6)} \tag{26}$$

$$N = w\sqrt{\frac{M}{S}} \tag{27}$$

$$D = \left[R + (1 + b)\frac{A^2}{r}\right](SM)^{-1/2} \tag{28}$$

$$v_0 = e_0 A/r\sqrt{SM} \tag{29}$$

$$y_0 = e_0 A/rS \tag{30}$$

These steady-state velocities and amplitude response curves have been plotted in Figs. 5 and 6 for various values of the damping factor D. Curves *1* are drawn for $D = 0.01$ which approximates a light-valve operated at constant current with a 40-db peak. Curves *2* have $D = 0.316$ corresponding to a 10-db peak. Curve *3* is drawn for $D = \sqrt{2}$, which just eliminates the amplitude peak. Its amplitude

response is flat up to one octave below resonance, has a 3-db loss at ribbon resonance, and droops 12 db per octave at high frequencies. Curve *4* shows the impractical case of $D = 10$. Its response is inefficient and nearly flat on the velocity scale, drooping 6 db per octave on the amplitude scale.

(5) TRANSIENT RESPONSE (FIG. 7)

Related to the steady-state characteristic, per equation *26*, is the response of the light-valve to "transients"; that is, shock impulses. The nature of these shocks may be electrical (switching clicks) or mechanical (overload clash). Assume that at $t = 0$ the voltage jumps from zero to e_0. One may transform *26* into the operational form

$$\frac{y_x}{y_0} = \frac{1}{1 + P^2 + DP} \tag{31}$$

with

$$P = \frac{d}{dx} = \sqrt{\frac{\overline{M}}{S}} \cdot \frac{d}{dt} \tag{32}$$

The abscissa unit x is such that a full vibration cycle of the undamped ribbons at their resonance frequency corresponds to an increase of x by 2π.

(*5.1*) *Damped Oscillations.*—For $D < 2$ the transients are free damped vibrations according to the equation

$$\frac{y}{y_0} = 1 - \frac{1}{F} \cdot \epsilon^{-Dx/2} \cdot \sin (Fx + \theta) \tag{33}$$

with

$$F = \sqrt{1 - \frac{D^2}{4}} \tag{34}$$

and

$$\cos \theta = \frac{D}{2} \tag{35}$$

Curve *1* ($D = 0.01$) follows the equation

$$\frac{y}{y_0} \doteq 1 - \epsilon^{-0.005x} \cdot \cos x \tag{36}$$

which is very poorly damped.

Curve *2* ($D = 0.316$)

$$\frac{y}{y_0} \doteq 1 - 1.01\epsilon^{-0.158x} \cdot \sin (0.99x + 0.141) \tag{37}$$

This curve is much better damped and is therefore plotted on a wider scale to follow individual vibrations.

Curve *3* ($D = 1.41$)

$$\frac{y}{y_0} = 1 - 1.41 \cdot \epsilon^{-0.707x} \sin (0.707x + 0.785) \tag{38}$$

The damping is so great that the ribbon overshoots only 6 per cent.

(5.2) *Aperiodic Damping.*—For $D \geqq 2$ the transient decay is aperiodic according to

$$\frac{y}{y_0} = 1 - \frac{1}{n-m}\left[\frac{1}{m}\epsilon^{-mx} - \frac{1}{n}\epsilon^{-nx}\right] \tag{39}$$

with

$$m = \frac{D}{2} - \sqrt{\frac{D^2}{4} - 1} \tag{40}$$

and

$$n = \frac{D}{2} + \sqrt{\frac{D^2}{4} - 1} \tag{41}$$

Curve 4 ($D = 10$) is drawn according to

$$\frac{y}{y_0} \doteq 1 - 1.01\epsilon^{-0.1x} + 0.01\epsilon^{-9.9x} \tag{42}$$

It is seen that due to overdamping the response is sluggish. From the transient as well as the steady-state point of view a damping factor between 1.2 and 1.4 is most desirable.

(6) POWER CONSUMED BY FEEDBACK COIL

The voltage delivered by the feedback amplifier is about proportional to frequency, and at resonance nearly enough to cancel the driving voltage. The current is inversely proportional to the undamped mechanical ribbon impedance; hence

$$e_F \doteq -e_0 N \tag{43}$$

$$i_F \doteq i_0(1 - N^2) \tag{44}$$

$$W_F = -W_{drive} \cdot N(1 - N^2) \tag{45}$$

This reaches a maximum at

$$N_m = \sqrt{\frac{1}{3}} \tag{46}$$

which for a valve strung to 10,000-cycle resonance corresponds to 5800 cycles. The maximum power consumed is

$$W_{max} = -W_{drive} \cdot \sqrt{\frac{1}{3}} \cdot \left(1 - \frac{1}{3}\right) = 0.355 W_{drive} \tag{47}$$

The feedback amplifier absorbs at most 8 db less than the low-frequency driving power of the light-valves. At this power level low distortion is not very essential because the second harmonic falls to the frequency

$$2N_m = 1.16 \tag{48}$$

which usually is beyond the transmission range of the recording and reproducing channels.

DISCUSSION

MR. KELLOGG: In most of the applications of the feedback principle the purpose has been to provide linearity and constant input-output ratio over a wide frequency range. It is my understanding that the application which we have just heard described does not undertake this, but merely employs feedback to damp out a resonance peak. That being the case, I can see that certain otherwise difficult problems are avoided. Since only a narrow frequency range need be covered, transformers in the circuit are not a menace to stability, and the fact that a recording galvanometer is essentially a constant amplitude device, whereas the voltage fed back is proportional to velocity rather than amplitude, does not cause any embarrassment. Is this a correct interpretation?

MR. ALBERSHEIM: Yes; the interpretation is correct.

MR. REICHES: By the use of the Heavyside unit function, the authors have shown that with feedback it is possible to eliminate or greatly to minimize the occurrence of the transient described by the unit function. It is probably true that every piece of equipment built and used by us today is subject to the production of an impulse transient which can occur whenever the power-factor of the equipment is other than unit. This type of transient, in all probability, is a large contributing factor to harshness and raspiness of speech in linear systems. Depending upon how far the feedback effect is carried, one would almost expect to hear the difference between two recordings, one with and one without the feedback light-valve amplifier. Sounds that are sharp in build-up, which may be found in words such as *cook* and *book*, should be improved.

Possibly the term "impulse" transient should be better defined: It is a term sometimes used to describe the transient produced by a discontinuity in either the electrical or magnetic field, the transient being produced by the field which is double-valued at the same instant. The clashing of the light-valve ribbon may produce such a transient.

However, it is further necessary to ask whether the other type of transient has been improved. It is sometimes called the "hyperbolic" transient, taking its name from the fact that the rate of growth of sound in general is a hyperbolic function of the form. This transient is largely determined by the phase-shift through the system between the various sine-waves forming the complex sound.

Black points out that a feedback amplifier may have a phase-shift exactly equal to the feedback network $+180°$; however, still considering the degenerative case, it seems possible that the phase-shift through the system may be aggravated. Offhand, the circuit shown by the authors may tend to approximate a linear phase-shift condition. I wonder whether any evidence exists showing that the condition due to non-linear phase-shift has been improved.

MR. ALBERSHEIM: The two types of transients named by Mr. Reiches are interrelated just as are the "impulse" and the "steady-state" response of a system.

To respond faithfully to an instantaneous impulse, a transmission circuit must have a steady-state frequency characteristic that is flat from zero to infinity. Generally, large amplitudes and slow decay of transient oscillations will correspond to sudden shifts of the steady-state amplitude and phase characteristics near the frequency of the transient disturbance.

The steadying effect of feedback upon the light-valve has been demonstrated by recordings of steady-state square-wave signals as well as of single impulses.

A CONSTANT-TORQUE FRICTION CLUTCH FOR FILM TAKE-UP*

WILLIAM HOTINE**

Summary.—*An analysis of frictional take-up devices in general use discloses the reasons for their failure or improper operation. An improved friction clutch is described and analyzed, which embodies means for canceling the effect of a varying coefficient of friction encountered at variable slip speeds, thus maintaining a constant torque at the take-up spindle. Automatic declutching occurs when the load exceeds the amount of torque transmitted, thus protecting the film from excessive tension, and eliminating declutching levers and ratchets when rewinding. The novel construction enables bidirectional operation, both in direction of rotation and in direction of transmission of torque.*

Important factors that should be considered in motion picture equipment design are reliability, efficiency, and protection of the film. The film take-up device, which is an important functional unit of all motion picture machinery, should naturally be designed and constructed with these factors in mind, as it is an integral part of the film-handling mechanism. Proper functioning of the take-up device enables the highest quality of performance of the associated machine, while poor take-up operation may not only adversely affect the performance, but may cause film damage. In considering a take-up design, the importance of reliable, safe operation should outweigh any question of economy and simplicity.

Let us examine the take-up problem. The film is leaving the machine at a constant linear speed, and is wound on the take-up reel at a constantly increasing diameter, so that the rate of rotation of the take-up reel is constantly decreasing. During the take-up process, the film tension should not exceed a safe value. The film should be wound evenly and firmly on the reel, so the film tension should not fall below a safe minimum value. The take-up spindle, therefore, should be driven at a varying speed, and at a definite, limited torque.

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

The highest speed will occur when the film starts winding on the take-up reel hub, and the limit of torque will be that which produces a safe film tension at this point. In most motion picture machinery, the take-up spindle is driven at this speed and torque by means of a slipping frictional device, such as a belt slipping on a pulley, or a friction clutch.

The slipping-belt take-up device is quite widely used and has the advantages of simplicity and economy. The torque transmitted to the take-up spindle is equal to the product of the pressure of the belt on the pulley surface, the radius of the pulley surface, and the coefficient of friction between the belt and pulley. The pressure of the belt on the pulley depends on the belt tension, which is hard to maintain at a uniform value. The area of contact between belt and pulley is small, resulting in high unit pressure which tends to wear or polish the pulley, changing the coefficient of friction. The only constant factor is the pulley radius. The slipping-belt take-up device is not a preferred method, from the standpoint of reliability, as the take-up torque may change at any time due to changes in the factors in the torque equation.

The friction-clutch take-up device offers a more reasonable solution to the problem, combining simplicity and economy with better stability of operation than the slipping belt. An ordinary friction clutch may be described as comprising a rotating driving member, a frictional element, and a rotating driven member which directly drives the take-up spindle. These elements are held in frictional engagement by the pressure of a spring. The torque transmitted to the take-up spindle is equal to the product of the mean radius of the members, the spring pressure, and the coefficient of friction of the members and the frictional element. Wear can be reduced by design for small values of unit pressure on the frictional elements. The spring pressure can be easily regulated and will remain substantially constant, as will the coefficient of friction. The friction-clutch take-up device is to be preferred to the slipping belt, as reasonably reliable operation can be expected. The spring pressure, however, is the largest factor in the torque equation, and in a typical design the take-up torque will vary almost directly as the spring pressure, thus requiring a critical spring pressure adjustment. At the low spring pressures encountered, a slight lessening in spring pressure caused by wear of the clutch elements might easily reduce the take-up torque to an insufficient value. Careful readjustment of the spring pressure

is required to prevent an excessive take-up torque with resultant damaging film tension. It can therefore easily be seen that an improvement in friction clutches in which there would be a reduction of the spring pressure factor in the torque equation, and in which the wear of the frictional element would have a smaller effect in reducing the spring pressure, would be desirable.

The improved constant-torque clutch to be described embodies the above-mentioned desirable characteristics in its construction and design. Fig. 1 is a cross-section in front elevation of a take-up device for use on a 16-mm projector, using this improved friction clutch. The supporting arm carries a sleeve shaft *24* rotating in a bearing, with driving pulley *22* fastened on one end of the sleeve, and driving

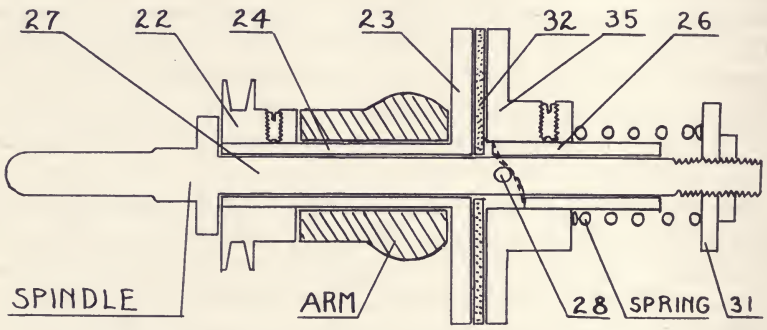

FIG. 1. Cross-section of take-up device.

clutch-disk *23* fastened on the other end. The driven shaft *27* has a thrust shoulder and take-up reel spindle on its left-hand end, and is free to revolve inside the sleeve. The round driving pin *28* extends radially from shaft *27*, to engage the cam surface on the end of cam sleeve *26*, which is free to revolve around shaft *27*. The driven clutch-disk *35* is fastened to cam sleeve *26*, and is held against friction washer *32* by the spring. Adjustment of spring pressure is made by nut *31*.

In operation, a belt drives the pulley in a clockwise direction, viewed from the left-hand side, revolving the sleeve shaft and the driving clutch-disk, and imparting a torque to the driven clutch-disk *via* the friction washer. The torque of the driven clutch-disk is transmitted to the driven shaft by means of the driving-pin and the cam surface on the end of the cam.

In the ensuing discussion the following nomenclature will be used:

F = force of spring pressing on clutch-plate.
f = total force pressing clutch-plates together.
f_p = force between driving-pin and the wall of the cam.
f_a = component of f_p in the axial direction.
T = torque delivered by the clutch to the load.
R = radius of gyration of clutch-plate.
r = radius of effective point of contact between the driving-pin and face of cam.
β = angle between a tangent to the cam surface and a diameter of the shaft.
λ = the coefficient of friction between the frictional element and a clutch-plate.

It can be seen that the spring pressure is exerted against the driving-pin in an axial direction, and part of the spring pressure is exerted in engaging the clutch-disks. The total force pressing the clutch-plates together is equal to the force of the spring minus the axial component of the force between the driving-pin and the cam surface. This relation may be expressed by

$$f = F - f_a \tag{1}$$

The axial force is the component along the axis of the total force f_p between the pin and the surface of the cam, and therefore:

$$f_a = f_p \cos \beta \tag{2}$$

The torque delivered to the shaft is equal to the radius of the point at which the pin presses against the cam surface multiplied by the component of the force on the pin which is tangential to the shaft. This relation is expressed as

$$T = r f_p \sin \beta \tag{3}$$

If we divide *2* by *3* we obtain the relation between the axial force and the torque; thus

$$f_a = \frac{T \cot \beta}{r} \tag{4}$$

If the value of f_a given by *4* is substituted into *1*, there results

$$f = F - \frac{T \cot \beta}{r} \tag{5}$$

The torque is equal also to the radius of gyration of the clutch-plate multiplied by the tangential force between the plates. The

latter is equal to the force pressing the plates together multiplied by the coefficient of friction. Hence we may write

$$T = R\lambda f \tag{6}$$

If we eliminate f from equations 5 and 6 there results

$$T = \frac{R\lambda F}{1 + \frac{R}{r}\lambda \cot \beta} \tag{7}$$

Equation 7 gives the torque delivered to the take-up spindle in terms of the various mechanical constants of the mechanism.

The torque delivered by the clutch will be a constant for a given adjustment of the spring pressure, as shown by the above derivation. The torque can never exceed this constant value, as an additional load will automatically lessen the torque transmitted to the driven clutch-disk as the spring is compressed by the climbing motion of the driving-pin up the cam surface, increasing the axial force on the driving-pin. The film is thus protected at all times from a damaging tension. A constant torque at the take-up spindle means that the film tension will be inversely proportional to the radius of the film pile on the reel. If this radius increases from two to seven inches during the take-up operation, it follows that the film tension at the end will be only 30 per cent of that at the start. The ordinary clutch does not deliver a constant torque at a variable speed because the coefficient of friction decreases with increased slip-speed of the clutch faces. In winding film, when the film pile increases in diameter, thus slowing down the take-up reel and increasing the slip-speed of the clutch faces, the torque of the ordinary clutch decreases, resulting in a loosely wound film pile at the larger diameter. This condition is aggravated by the increased film weight at large diameters. If the spring pressure is adjusted for sufficient torque to overcome this condition, the film tension at the start of the winding is generally excessive, and is conducive to film damage. The improved clutch delivers a constant torque at variable speeds, because any change in the coefficient of friction substantially cancels itself out, and has little effect on the torque, as can be seen by inspection of equation 7. This constant torque can not be exceeded, thus affording definite protection from excessive film tension under all conditions, and as the torque is maintained regardless of the film pile diameter, a tightly wound reel always results, even with film

tensions ranging down to three-quarters of an ounce at the periphery of the reel.

Fig. 2 graphically indicates the smaller variation in output torque of the improved clutch. Spring pressure in pounds is plotted against output torque in foot-pounds for the ordinary clutch, and for the improved clutch designed for the same output torque. The smaller variations in torque with variations in spring pressure shown in the curve for the improved clutch, together with the much larger spring pressures required for a given value of torque, indicate a more stable condition which would tend to maintain an adjustment and produce more reliable take-up operation. The angle β of the cam surface determines the slope of the curve for the improved clutch. As the

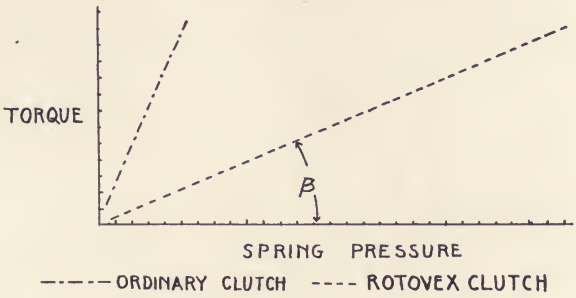

FIG. 2. Variation in output torque.

cam surface may be constructed to give bidirectional operation, different angles on the two sides of the cam will enable different torques to be transmitted with the same spring pressure, depending upon the direction of rotation.

Other features of the improved clutch are: Automatic declutching of the plates when the take-up spindle is driven in reverse, as when rewinding; ratchets and declutching levers can be dispensed with, further simplifying construction and operation of the film take-up mechanism. The direction of transmission of torque can be reversed with identical operation; that is, the power can be applied to what was formerly the driven member, in adapting the construction to suit other purposes such as brake mechanisms.

In conclusion, the writer wishes to acknowledge the able assistance of Dr. Charles B. Aiken in the preparation of this paper.

RECENT DEVELOPMENTS IN PROJECTION MECHANISM DESIGN*

EWALD BOECKING AND L. W. DAVEE**

Summary.—*A 35-mm motion picture projector mechanism is described. A theoretical discussion of the operation of single and double-shutter mechanisms shows the advantages of each and covers points that should be considered for improving screen reproduction from mechanisms generally.*

With the passing of each year, the requirements of the motion picture industry and the projection of the picture in particular have become more and more exacting. These improvements include such items as greater accuracy in projection, increased operating efficiency, lower maintenance, and longer life. Thus the demands upon the projection mechanisms have become increasingly severe.

The acceptance by the industry of certain standards which were dictated by previous use, rather than a redesign based upon an engineering foundation, has resulted in the fixing of physical dimensions and shaft speeds which for commercial reasons can not be changed without the coöperation of the industry. If certain of these standards could be changed marked improvement in mechanism design could be effected.

These design features include the height of the optical centerline of the projection mechanism above the separation line between the sound-head and the projection mechanism; the film distance between the optical centerline of the picture and the optical centerline of the sound-track; the projection of 24 frames per second; the speed of the shutter and intermittent cam shafts of 1440 rpm; and the speed of the main drive-shaft which couples the mechanism to the sound-head.

Having these standards already in existence it becomes an engineering necessity to design any new projection equipment to fulfill those requirements plus those mechanical and operating features

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** Century Projector Corp., New York, N. Y.

desired in the final product. As in the design of any scientific or mechanical device the stability and inherent durability of the product must first begin with perfection in the basic design and it must be built on a foundation of engineering knowledge proved by practical operating experience.

We shall begin our discussion with the main supporting frame. A mechanism involving rotating shafts, meshing gears, and accurate optical alignments must be assembled on a firm foundation free from

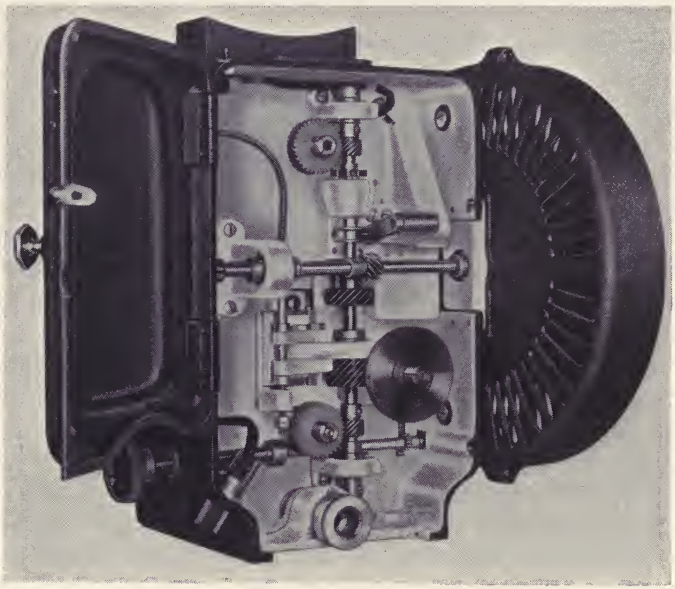

FIG. 1. Rear view of single-shutter mechanism.

the dangers of warping and guarded against shaft alignments when subjected to relatively severe shocks which necessarily occur, at times, in shipment or during installation. In Fig. 1 we see a center frame entirely enclosed in a cast case made in one piece. The center frame is therefore substantially supported on all sides, making any displacement of critical alignments virtually impossible. With the exception of the upper and lower sprocket-shafts, all the other shafts are supported by brackets attached to the main frame. In this design each shaft is placed in perfect alignment without the necessity of using alignment reamers, gauges, or other special tools.

Gear Design.—The fundamentals of gear design are well known. Having definite requirements regarding load, ratios, shaft speeds, and operating functions, there is almost no choice in the selection of the gear design to accomplish efficiently the work to be done. Many gear designs are selected, however, without first studying the factors governing their operation and taking advantage of the type of gearing which best suits the purpose.

Any pair of gears which are properly designed for pitch diameter, shape of gear teeth, pressure angles, *etc.*, must, for efficient, quiet operation run on shaft centers dictated from the basic design rather than from the trial-and-error methods sometimes followed by a number of assembly men. The prevalent use of grinding compound in fitting gears, to quiet their operation is in general due to the inaccuracies of manufacture or the failure of the mountings used to position the shaft centers correctly. These errors cause tooth interference which can at best be eliminated only partially, and always result in inefficient gear-trains. If grinding compounds are used it is practically impossible to remove the cutting abrasives entirely and they continue to cause excessive wear throughout the life of the mechanism.

There are no grinding compounds used in the assembly of the gear-train shown because each pair of gears has been designed correctly for the purpose for which it is used, and the shaft centers are fixed exactly by the mounting bracket design coupled with the use of ball-bearings insuring perfect shaft centering.

Bearings.—The bearings in this mechanism are of two types. They have been engineered to give long, trouble-free service in the particular positions in which they are used.

Except in the slow-speed upper and lower sprocket-shafts, sealed-for-life ball-bearings have been adopted for all the shafts in the mechanism. There is much misinformation and confusion regarding the use of ball-bearings in the reduction of wear and the maintenance of accuracy in machine design, and it is therefore desirable to review some of the facts regarding the operation of these bearings.

Friction is a phenomenon that works for both good and evil. The effect of friction in a projection mechanism can cause only one result, increased driving power with a consequent increase in reflection of gear disturbances transmitted to the sound-head. Mechanically, friction causes the generation of heat and the increase of wear. Sliding friction is always present in plain bearings and increases or decreases depending upon the type and kind of lubricant used, not

the amount. Higher-speed shafts naturally generate more heat and increase the amount of wear.

In order to eliminate friction ball-bearings were developed, and their advantages appeared so promising that in Europe, and then in America, the most exhaustive scientific research was instituted to determine the fundamental principles underlying their theory. The ball-bearing is today, therefore, distinguished from all other forms of anti-friction in having a thoroughly sound background of scientific principles governing its design. The load-carrying capacity and expected life are not merely matters of experiment but are subject to as accurate mathematical determination as is the strength of a steel bridge.

Friction in any bearing is very largely shown by the amount of wear that takes place. In a ball-bearing properly sealed against dirt, wear for all practical purposes can not be measured even after long, hard service. Ball-bearings are the only type of anti-friction bearing that can be successfully sealed and lubricated for life. Evidence of these long-life characteristics is found in the thousands of sealed-for-life ball-bearings that have run for many years without the least attention.

Ball-bearings do not suddenly break down for no apparent reason, nor do they wear out in the sense of loss of dimensions or accuracy of positioning characteristics. In a ball-bearing running under load the balls and raceways are subject to continuous repetition of stresses which, after long and carefree service, begin to show the effect of structural fatigue. This in no way impairs the usefulness or operating qualities of the structure until after an actual breaking down of the material occurs. This is not a sudden occurrence and can be predicted with remarkable certainty. All other causes of failure are premature and can be prevented.

A good many years ago the principle of preloading bearings to reduce deflection within the bearing, and therefore increase the rigidity of the shaft support, was developed. The effect of preloading, however, which bears a most direct relation to wear, and which is frequently passed unnoticed by machine designers, is the fact that correctly applied preloading increases the useful life of ball-bearings and in so doing eliminates the noise usually associated with their use.

Resistance to deflection as a result of preloading has a most important influence upon machine life in that it assures definite maintenance

of accuracy limits within which machine parts are designed to operate for best performance and endurance.

Thus if mating gears are held very closely to the pitch-line relationship for which they are generated minimum gear wear will occur and maximum life and freedom from noise will result. Special importance attaches to the ability of ball-bearings to achieve this result, for it is well known that if carefully located gears are permitted to change position gradually through frictional wear in the supporting bearings, and the gears have worn out of pitch, no amount of subsequent bearing alignment can restore them to their original efficiency and quietness.

Where closely and accurately fitted bearings are required, as in a projector mechanism, considerable preliminary adjusting has always been necessary before gears and shafts would operate properly. In addition, these bearings when worn in service, usually can not be replaced without delay.

With the standardization and closely held limits permitted in ball-bearing manufacture it is now possible to eliminate all handwork and replace bearings without special skill, with the assurance of maintaining the original accuracy of the mechanism.

Primitive is the idea that ball-bearings should be provided with a means of relubrication. This simply means that either too much grease, unclean grease, or the wrong kind will sooner or later be added. It likewise means that either the seals or the original lubricant is not good enough. The bearings adopted in this mechanism are therefore sealed for life, and never require maintenance or relubrication of any kind. They are bearings of proved performance, lubricated and sealed to protect and preserve their accuracy by the best means that the widest experience in the industry can devise. There are at present over 10,000,000 of these self-sealed bearings now in use giving trouble-free, dependable service.

Each bearing is mounted in a bracket attached to the main frame by means of carefully machined surfaces and heavy mounting screws. In this method of design entire shaft and bearing assemblies may be interchanged without the necessity of hand-fitting or shaft alignment. The design also precludes any possibility of bind-up.

The upper and lower sprocket-shafts have been designed using oilless type bearings. In shafts such as these, ball-bearings are not warranted for several reasons. The speed of rotation is relatively slow, and therefore they are subject to very little wear. This type of

bearing should properly be called "oil-plus" instead of oil-less. They are made of 99.8 per cent pure powdered bronze, compacted or squeezed together under hydraulic pressure, forming a homogeneous capillary structure. These fine particles are then permanently joined together by a heat-treating process. After the heat treatment, the metal is full of tiny capillary pores too small to see without a powerful magnifying glass but able to soak up oil like a sponge. It is then impregnated to $^1/_3$ of its volume with pure acid-free oil.

The moment the shaft begins to rotate in this bearing the pressure and movement instantly cause a film of oil to be formed between the moving parts. The bearings therefore do not require any additional lubrication over long periods of service. Tests recently completed indicate that after 1,419,824,000 revolutions of a shaft in these bearings, without a stop and without one added drop of lubrication, neither the shaft nor the bearing showed signs of wear. At 360 rpm, the speed of the upper and lower take-up shafts, one can make his own calculation as to their probable life. Channeling of shafts and bearings has thus been eliminated with an assurance of long service free of bind-up. It therefore can be seen that practically no lubrication is required that will come into contact with the film during projection, causing oil marks and the collection of dirt.

The main drive-shaft, running in its sealed-for-life ball-bearings, is designed so that its centerline distance from the picture aperture is the same as has been adopted through custom. Any regular sound-head coupling gear and shaft will fit properly on this driving-shaft, but the small 17-tooth pinion usually used as a mechanism drive is not used as such. This small gear is used only as a clutch member with or without teeth. The other part of the clutch is the main drive-sleeve of the mechanism. The whole clutch assembly clamps together as a complete unit so that the power supplied from the sound-head drives directly to the vertical shaft through the main drive-gear.

Gears.—Each gear in the mechanism has been designed to do a particular job. There are no gears in the train that merely transfer motion from one part of the mechanism to some other part. As a result fewer gears are used, resulting in a consequent reduction in friction and wear.

The sound-head drives directly to the vertical shaft through a gear specially designed for the smooth efficient transmission of power. From this vertical shaft are then driven all the other operating parts of the mechanism. The advantages of this system are apparent.

Backlash, the cause of jumping gear-trains, and the introduction of excessive travel-ghost have been reduced to a minimum. Only two gear contacts exist between the intermittent cam and the shutter blades. By the same token only two gear contacts exist between the main drive and the shutter or the intermittent. Such design has contributed much toward making this the quiet, stable, and efficient mechanism which it is.

Scientifically designed, hunting-tooth spiral gears throughout assure quiet operation and an absence of reflected, varying loads back to the sound-head gears. All the steel gears are heat-treated and hardened to contribute to longer life with a consequent reduction in

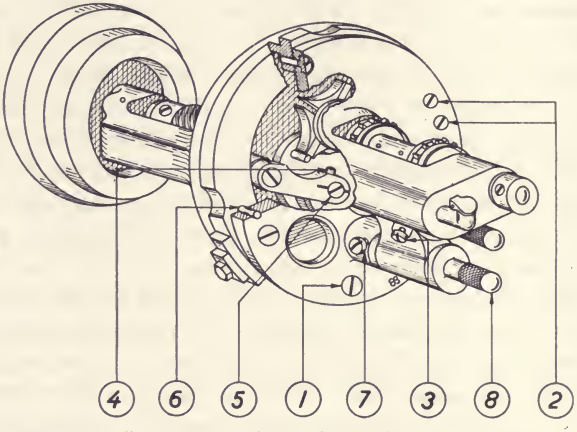

FIG. 2. "Century" projector intermittent movement.

the possibility of developed backlash. All gears have a face of $^1/_2$ inch or more and are meshed steel against fiber. The fiber gears are oil-impregnated so that only that amount of lubrication need be supplied to compensate for losses due to evaporation, *etc.*

Intermittent Movement.—The intermittent movement is an outstanding example of precision workmanship. It has been designed with four bearings, two on the cam-shaft and two on the sprocket-shaft. Perfect alignment is therefore maintained between the two.

This is a direct-drive movement having no gears inside the case. The flywheel is mounted directly on the cam-shaft with no gears between it and the cam. The flywheel, of course, supplies the power required to move the starwheel, sprocket, and film. Without the flywheel this intermittent load would reflect back into the gear-train

causing considerable disturbance. There being no gears between this intermittent load and the flywheel driving-power, the noise of operation is reduced and the operation of the starwheel made more positive.

The four bearings are supported in heavy arms and are automatically supplied with lubrication through scientifically designed oil-channels. The outer bearings are of the same oil-less design as is used on the upper and lower sprocket-shafts and, in addition, are supplied with oil which, as needed, filters through the capillary tubes of the bearings. These tubes form an extremely fine filter for the oil and allow only that amount required for satisfactory lubrication to reach the shaft.

The intermittent sprocket is designed in accordance with the accepted standards of such sprockets and is heat-treated, hardened, and ground to $^{1}/_{10,000}$ of an inch, as are also the cam, cam-pin, starwheel, and shafts.

A micrometer adjustment is provided so that the distance between the cam and the starwheel may be changed while the mechanism is running. With this adjustment the intermitted may be set for the best screen results together with quietness of operation.

The intermittent pad-shoe assembly is mounted directly on the case of the intermittent, and is designed so that each shoe is self-aligning to the sprocket with pressure applied to each shoe equally. With this type of construction, uniform film motion through the trap-and-gate assembly is assured with a freedom from unequal wear and film buckle heretofore unattained.

The intermittent movement is easily removed from the operating side of the mechanism so that accidental damage to the sprocket is minimized and the removal of gears rendered unnecessary. Only the flywheel has to be removed. The movement may be replaced in the mechanism in perfect time with the shutters without the necessity of marking gears or dowel-pin arrangements. Timing the shutters with the intermittent is also accomplished without the use of aligning tools and without removing any of the operating parts such as lenses, *etc.*

The Operating Side.—A full-width symmetrical door is provided to allow ready access to the operating side of the mechanism and gives plenty of room for threading or servicing. All spring tension in pad rollers and gate is obtained with coiled springs under compression, so that there is minimum danger of spring breakage. This

construction also reduces the possibility of accidentally changing tension adjustments by bending the springs, catching of cleaning-cloths, *etc.*

The pad roller construction is a complete operating unit. The tension is obtained from a construction employing two coiled springs under compression, locating two steel balls into recesses of the hardened steel hub of the pad-roller shaft. With this type of self-con-

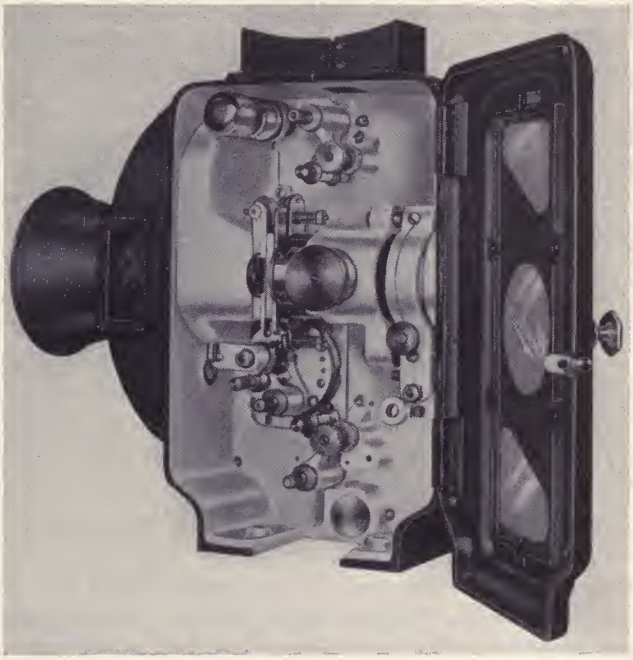

FIG. 3. Operating side of mechanism.

tained arrangement the complete pad-roller assembly may be removed from the mechanism for replacement, cleaning, or adjustment.

In addition to being complete in its working parts, the strippers are included as an integral part of the pad-roller hub. Thus the stripper is always in adjustment and is automatically positioned when the pad-rollers are closed. This feature makes it most convenient for sprocket replacement. With the pad-rollers in open position, the sprockets may be replaced without removing or readjusting any other parts of the mechanism.

In threading the film, the pad-rollers are opened and provide a gauge for setting the loop sizes above the film-trap and below the intermittent sprocket. The film is threaded tight over both pad-rollers, and the loop sizes are automatically set when the rollers are closed.

The film-trap and gate have been designed to fill not only the technical requirements for perfect picture reproduction, but also to provide the most desirable features from an operating standpoint. The film-trap is a complete assembly readily removable from the mechanism for inspection and exactly interchangeable without readjustment. It includes interchangeable film-shoes and studio guides, heat-treated, hardened, and ground. The upper guide-roller is designed so that the guiding face is integral with the shaft on which it is rotating, and is ground on the same centers on which it is mounted in the film-trap. This construction assures perfect accuracy of the guiding face and eliminates the side weave that will occur if there is any eccentricity of the surface.

The film-trap is mounted to the main frame with three large screws, and is held in accurate alignment to the optical centerline by means of the large ground pad, which forms the base of the film-trap, and two dowel pins so located that the complete trap assembly may be moved forward and back parallel to the optical centerline. This adjustment is provided so that perfect alignment may be obtained between the trap shoes and the faces of the intermittent sprocket.

A number of experiments have been made to determine the best relation of the alignment between the trap shoes and the sprocket. From jump measurements which were made, it seems desirable to set the shoes slightly ahead of the sprocket face so that effectively the film position under tension is exactly parallel to the face of the trap shoes.

The tops of the trap shoes are curved back away from the flat surfaces of the shoes, allowing the upper loop to be made in back of the centerline of the film in the film-trap. The reason for this will be discussed under the explanation of the film-gate operation.

The lens-holder and film-gate mounting is a complete unit, readily removable from the mechanism. As in the case of the film-trap it also is mounted to the main frame by means of a large accurately ground pad and held securely in position with large screws. The complete assembly is also located with two dowel pins so designed

that it may be moved toward the film-trap or away from it. With the film-trap properly located with respect to the intermittent sprocket the gate may then be set to its proper distance from the trap, giving an optimal operating condition for each unit.

The lens-mount is designed for "half-size" lenses, and may be used with any lens by means of adapters.

The opening and closing of the gate as well as its accurate alignment with the trap is accomplished by means of a large sliding tube mounted inside the frame of the lens mount. Both the inner surface of the frame and the outer surface of the tube have been accurately ground to provide a smooth, substantial mounting for the gate. When the gate opens and closes, it always moves on the optical centerline and can by no bending or displacement of the mounting fail to register in perfect position with the trap.

The gate opening and closing knob located in the center of the mechanism contains all the tension springs, locks, *etc.*, associated with the gate movement. Here again there are no flat springs to get out of adjustment.

A cam action inside the knob securely locks the gate in the closed position so that it is impossible to open it accidentally even though the spring tension were to fail. Two open positions of the gate provide for normal gate opening for threading, and the second and larger opening, which is about one full inch, gives plenty of room for trap-shoes and gate-pad inspection and cleaning, if necessary, without removing them from the mechanism. The gate is a real advance in design and was adopted after many models and designs had been discarded.

The gate-pads are mounted on the gate-plate, which is flat and accurately ground on both front and rear surfaces, by means of equalizing levers which insure exactly the same film tension on both sides of the gate. The tension is obtained by means of two large coiled springs under compression, and is adjustable from zero tension to a safe maximum. A safety stop is provided so that there is no danger of locking the film during projection.

At the top of the gate are mounted two guiding shoes, called upper loop stabilizers. These stabilizers rest against the film above the gate-pads, giving the film a slight bend backward from the trap-shoes. The result of this feature has been to prevent the reflection of disturbances to the film at the aperture caused by the changing upper loop.

Experiment has shown that no matter how long the film-trap was made or how securely the edges of the film were held, deflections of the film at the aperture could not be prevented unless a method such as described above was used. These deflections occurred as the upper loop changed its size during the projection of the picture while the film was stationary in the aperture. The resulting screen appearance was the same as diffusion in the lenses. The sharper focus of the picture on the screen is quite obvious with this new gate design.

The Shutters.—Theoretically if one edge of a 90-degree shutter intercepts a beam of light on the axis of the optical system at the

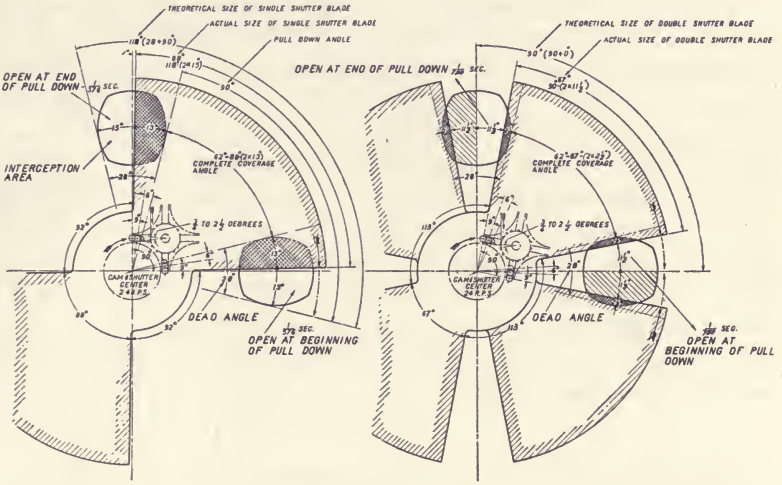

FIG. 4. Diagram of "Century" single and double-shutter interception.

time of engagement of the intermittent-cam pin with the starwheel, the trailing edge will leave this beam at the time the intermittent-cam pin leaves the starwheel. This relation is true with a Geneva-type 90-degree movement. It is the practice for almost all projector manufacturers to use this type of movement. (Fig. 4.)

However, the beam of light intercepted by the shutter is in reality of finite size and becomes appreciable in the operation of the projector mechanism. It is therefore no longer possible to consider shutter operation on the basis of its theoretical optimal operation and we must investigate the factors governing its effect on the picture reproduction.

One blade of the shutter, called the flicker blade, does nothing more than to increase the number of pulsations of light that the eye views until the persistence of vision gives the impression that a steady light is being projected. The higher the screen illumination the more critical the eye becomes of light variations. Therefore in the following discussion of shutter design it will become obvious that the higher the screen illumination the greater becomes our interference factors.

The average single rear-shutter mechanism requires a 95 to a 110-degree cut-off blade for reasonably good screen performance. This operation is dependent, of course, to some extent upon the speed of the projection lens being used. In our discussion we shall assume one lens size as a constant and relate all the discussion to it. These mechanisms referred to are the type which usually employ so-called 90-degree shutters. The average double-shutter mechanisms using double rear shutters according to the usual practice require cut-off blades of 70 to 75 degrees for optimal performance.

An investigation of the shutter problem has resulted in the design of a shutter combination that will give optimal operating results consistent with the physical dimensions that were decided upon. A higher-efficiency mechanism could be designed but its size would make it inconvenient for the average projection room.

Seven fundamental factors were considered in the design of the shutter on this mechanism:

(*1*) Heat on the aperture.
(*2*) Total screen illumination or shutter efficiency.
(*3*) Amount of travel-ghost allowed.
(*4*) Size of the light-spot at the point of cutting.
(*5*) Position of the shutter in the light-beam.
(*6*) The peripheral speed of the shutter-blade.
(*7*) Mechanical strength and wearing qualities.

A balance of all these factors must be made and the engineering considerations carefully weighed.

The total heat at the aperture, regardless of the cooling methods employed, obviously dictates the use of rear shutters, either single or double. The heat at the aperture should also be in proportion to the amount of light being transmitted.

The size of the beam of light intercepted governs the time that a shutter blade at any peripheral speed requires to cut off the light

completely. The peripheral speed of the shutter-blade also governs the time required to cut a beam of light of any given size.

If we consider a light-beam from the lamp-house mirror having an angle of about 20 degrees, the size of the spot 4 inches from the aperture will be about $2^1/_8$ inches in diameter. At a distance from the aperture of 5 inches this beam will be about $2^1/_2$ inches, which amounts to an increase of $17^1/_2$ per cent travel time of the shutter-blade. If the distance is increased to 6 inches the beam will increase to about $2^{15}/_{16}$ inches or an increase in travel time of 38 per cent.

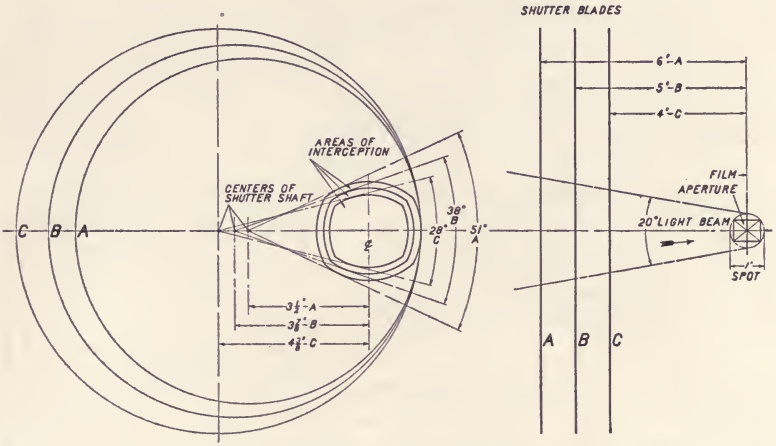

FIG. 5. Diagram of light-beam interception.

The peripheral speed of the shutter, which has a rotary speed of 1440 rpm, will be governed by the distance from the center of the shutter-shaft to the center of the beam of light. The arc of the shutter-blade at the center of the spot is the longest distance the shutters have to travel.

Assume that the light-beam where the shutter is located is $2^1/_8$ inches in diameter and the distance from the center of the shutter-shaft to the center of the light-beam is $4^3/_8$ inches. The shutter-blade then has to travel about 28 degrees to cover the spot, which amounts to about $7^3/_4$ per cent of one shutter revolution.

If the distance from the center of the shutter-shaft to the center of the light-beam is $3^7/_8$ inches and the spot of light is increased to $2^1/_2$ inches, the cutting angle will become 38 degrees or about $10^1/_2$

per cent of one shutter revolution. Should the spot of light increase to $2^{15}/_{16}$ inches and the distance from the center of the shutter-shaft decrease to $3^{1}/_{2}$ inches, then the cutting angle will increase to 51 degrees or about 14 per cent of one shutter revolution.

These angles of movement are called dead angles, and are a loss of picture projection time which can not be recovered after the mechanism has been designed and built, because of the physical limitations imposed by the design.

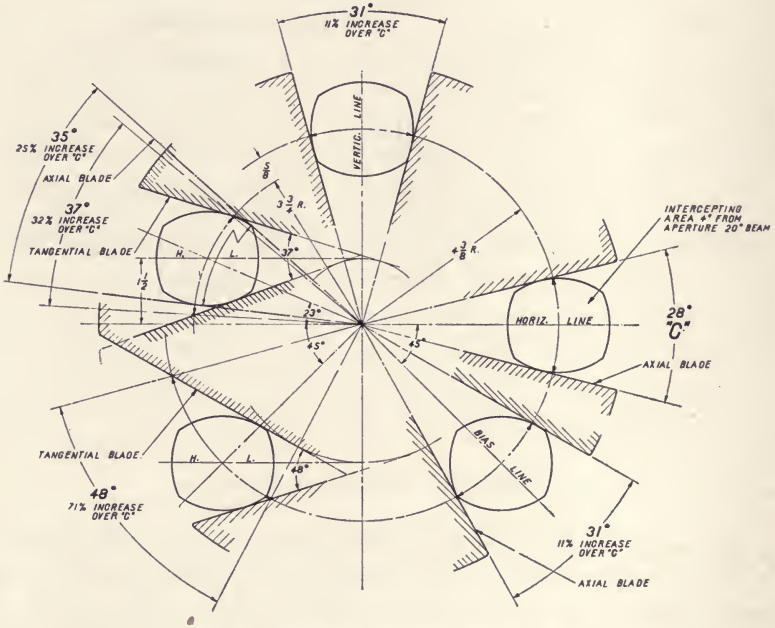

FIG. 6. Diagram of intercepting angle.

Considering a balanced shutter, a design having the cut-off specifications illustrated in case *C* (Fig. 5) would intercept the light-beam in 26 to 45 per cent less time than a design having the features illustrated in cases *A* or *B*. A correct conception of this relation would be as follows: if the conditions of picture reproduction in cases *A* and *B* are satisfactory for a given light-intensity on the screen, then the operation of the mechanism in case *C* would be satisfactory with shutter-blades of 10 to 23 degrees smaller angle.

Now let us consider the next step in the shutter design. (Fig. 4.) At a projection rate of 24 frames per second and using a Geneva-type intermittent sprocket pull-down, the starwheel movement time is theoretically $^1/_{96}$ of a second, which corresponds to 90 degrees or the fourth part of a complete shutter revolution.

Theoretically a film frame should not be moved before the light has been completely intercepted, and it should stop moving before the light is again transmitted. This means that a shutter should have a 90-degree cut-off blade plus the angle required to intercept the beam, which in our case is 28 degrees, or a total of 118 degrees.

In case *B* having a 38-degree cut-off angle the total blade would be 128 degrees. In case *A* having a 51-degree cut-off angle the total blade would be 141 degrees.

In practice, however, the cut-off angle of the blade can be made smaller than the angles shown and yet give good picture reproduction, so there must be some explanation for it.

As the cam-pin enters the starwheel slot it will travel about 9 degrees before the film starts to move. About 9 degrees before the cam-pin leaves the starwheel slot the film stops moving. During this 9-degree cam-pin travel the film does not move; therefore the shutter-blade can be designed with 18 degrees less angle than calculated, making it about 100 degrees.

The difference between this 100-degree theoretical shutter-blade and the angle of shutter-blade actually used can not be explained mathematically or mechanically. There are, therefore, other factors governing the shutter operation that must be considered, and which will influence the quality of reproduction from any mechanism depending upon how far the particular designer wishes to go.

From a number of experiments it has been determined that a motion picture would not look real if it were not for the inefficiency of the human eye, commonly known as persistence of vision, which allows the eye to dissolve one still picture into another one in a fraction of a second. This so-called identification deceiving act may need from $^1/_3$ to $^1/_6$ of a second. It seems that it has no effect upon reducing the size of the shutter-blade, however, and depends upon the frequency of the change and the amount of displacement occurring from one picture to another.

There is another factor about which we are most concerned, and this is the time the eye requires to recognize a picture after a dark period. This time factor is influenced very greatly by the brightness

of the picture during the transmission period, and appears to be about $^1/_{750}$ to $^1/_{1500}$ of a second with the usual screen illuminations used in practice. This would account for the 12-degree smaller angle that can be used on the shutter, bringing the total single-shutter cut-off blade down to 88 degrees. As the angle is decreased a consequent increase in screen illumination is obtained which decreases the time of perception of the eye to travel-ghost. Therefore a balance must be obtained at which the degradation of picture quality, because of these effects, remains within satisfactory limits.

In projector mechanism design using greater distances from the aperture to the shutter-blades and smaller distances from the center of the shutter-shaft to the center of the light-beam, these effects become greater and greater. With the mechanism design being discussed the cut-off blade angles were selected on the basis of picture quality and freedom from travel-ghost with its attendant picture degradation, giving higher screen illumination plus sharper definition than has heretofore been possible.

Another design feature that has to be considered is the direction of the shutter interception with respect to the light-beam—in other words, the position of the center of the shutter-shaft with respect to the optical center of the mechanism. (Fig. 6.)

If the area of the light-beam were circular it would make no difference where the shutter was placed; but as the area changes in shape the farther the interception point is from the aperture, this angle becomes of considerable importance. (Fig. 6.)

Locating the shutter-shaft center in a horizontal direction about $4^3/_8$ inches from the light-beam center, the angle of interception as explained before is about 28 degrees. If the shutter-shaft is located above or below the light-beam center, by using axial intercepting blades they would have to be 31 degrees wide or an increase of about 11 per cent in cut-off time.

Placing the shutter-shaft center about $1^1/_2$ inches above or below the light-beam center and $3^3/_4$ inches away, the intercepting area would be increased to 35 degrees or 25 per cent. Intercepting the same spot with a tangential blade, the intercepting angle increases still further to 37 degrees or 32 per cent over the original 28 degrees.

Intercepting a light-beam on an angle of 45 degrees and keeping the same shaft center and beam distance as in case *C* (Fig. 6) which required 28 degrees, an increase in interception time of about 11 per cent would occur; but if, in addition, tangential blades are used to intercept the beam, with the edges arranged to be horizontal at the

middle of the aperture, the angle again increases to 48 degrees or 71 per cent above the design of case *C*.

The design of the double-shutter mechanism is such that both shutters are located at the rear of the mechanism in order that the heat may be reduced at the aperture in accordance with the total light being transmitted. Each shutter is driven independently so that the driving load is divided between two sets of gears. Each shutter is mounted on its own ball-bearings; therefore there is no

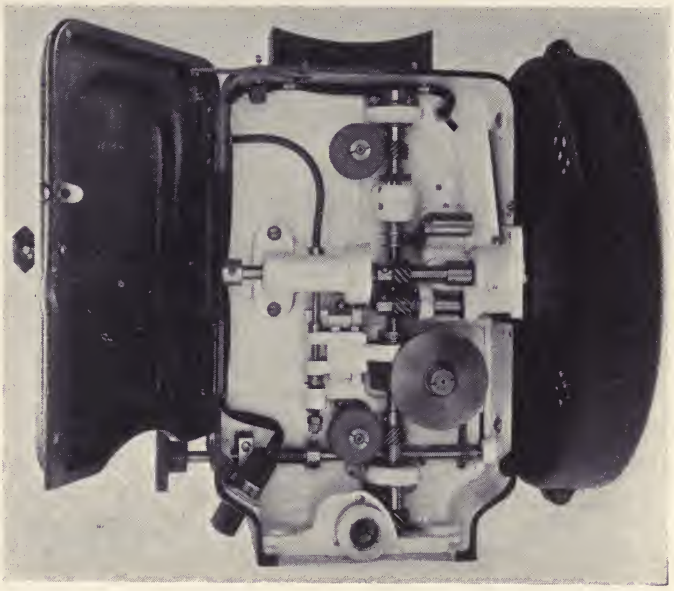

FIG. 7. Rear view of double-shutter mechanism.

sliding friction between them and each shaft speed is the same 1440 rpm as in the single-shutter unit.

In the double-shutter mechanism each blade has to travel only halfway through the light-beam for complete coverage of the light. This amounts to a reduction of this cut-off period of 50 per cent. Thus the double-shutter mechanism, in addition to the gain in light-beam interception time of 26 to 45 per cent as explained for the single-shutter mechanism, cuts this time in half so that a gain of 63 to 73 per cent is realized. Following the same line of reasoning as in the case of the 88-degree single-shutter mechanism the same facts apply to the double shutter. (Fig. 4.)

Therefore, if a 118-degree single shutter can be operated with 30 degrees less blade than is theoretically possible, then a theoretical 90-degree double-shutter blade can be operated at 60 degrees provided that the same amount of light is being projected on the screen. Due to the increase of about 19 per cent in the projected light and the reduction of 50 per cent in the cut-off period, 7 degrees or 25 per cent of the intercepting spot angle has to be added on each blade to bring the amount of travel-ghost content to the same relative value as on an 88-degree single shutter. Therefore a theoretical 90-degree double shutter can be operated at 67 degrees in a light-beam position *C*, at 70 degrees in a position *B*, and at 73 degrees in position *A*.

The light efficiency of the Century single-shutter and double-shutter mechanisms represents real values and with proper methods of measurements may be checked by illumination measurements made in any theater. The single-shutter mechanism has 88-degree blades with 92-degree openings, with an efficiency, of 51 per cent.

The double-shutter mechanism has 67-degree intercepting blades running in opposite directions. The efficiency calculation differs slightly from that of a single shutter and equals 59 per cent in a light-beam position *C*, 56 per cent in a position *B*, and 53 per cent in a position *A*. The double-shutter mechanism *CC* will deliver approximately 16 per cent more light than the single-shutter mechanism *C*. This amount, compared to a single-shutter mechanism using 95 to 110-degree shutter-blades, results in an increase in light from 25 to 51 per cent.

Of course, in the determination of shutter-blade sizes there is one very important consideration that should be mentioned. In the design of the gear-train between the shutters and in the intermittent movement, each pair of gears will contribute a certain amount of backlash which must be compensated for in additional degrees of covering. We believe that the design used in the present Century mechanism has as few gears as is possible, considering the speed of rotation and the change of motional direction between the intermittent and the shutters. Whatever advantage there may be in these mechanisms from this factor has been used in improving the appearance of the picture, rather than in reducing the shutter angles, and to give the additional illumination which could be obtained. We feel, therefore, that the design of these mechanisms has contributed much to the design standards of this industry.

REPORT OF THE STUDIO LIGHTING COMMITTEE*

Summary.—*Increasing interest in exposure meters is noted, with a concerted effort on the part of one manufacturer to provide studios with improved specially designed meters for each studio's individual need. "Arc" and "Inkie" equipments are being used more interchangeably on black-and-white and color sets as their respective design fits the cinematographers needs.*

In its endeavor to keep the Society informed of new and immediately anticipated development in technic and equipment for photographic lighting, the Committee submits this brief report. The report is necessarily brief since there have been no developments in new lighting equipment, and the technic has not changed appreciably since the last report was made.

The use of exposure meters seems to be growing, and a newly designed meter is now being introduced into active use in the studios. The designer of this meter has approached his problem with the idea that scene illumination is a dual problem for the cinematographer, in which the elements of illumination balance and prevailing illumination level must both be considered. The illumination balance is an artistic problem to be handled by the individual cinematographer's unique talent and experience in this field. The evaluation of illumination level is a technical problem. The new meter is designed to accomplish the task with a maximum of accuracy, and a great saving of time in the lighting set-up. It utilizes a translucent hemisphere as a means of collecting light; is calibrated in lens *f*/ values instead of in foot-candles; and the meters are individually calibrated to meet the requirements of different studio development technics. The hoped-for result is that the cinematographer can devote more attention to the artistic side of his work with a resulting increase in effectiveness of scene illumination.

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* Presented at the 1941 Fall Meeting at New York, N. Y.; received October 20, 1941.

Increasing numbers of small single-lamp "broads" for use with 750-w and 500-w "*MP*" and "*CP*" lamps are now making their appearance on the sets.

In Technicolor photography the use of "*Inkie*" light on the sets seems to be increasing. The use of the "*CP*" lamps with the Macbeth *Whiterlite* filters in the equipment has proved highly successful. In the past year cameramen have been taking advantage of the flexibility of "*Inkie*" equipment and the large variety of available sizes and possibilities for placement and concealment that they present, to bring out to the fullest the great potentialities of beauty in color photography.

A trend toward the use of "*Inkie*" equipment for top and key-lights in the illumination of small and medium-size sets is noted. The 5-kw and 2-kw "*Solarspot*" equipments are gaining in popularity, and large numbers of these comparatively small units are now employed.

At the present time carbon arc lamps are being freely used for black-and-white as well as color photography. Each type of lighting unit, whether carbon arc or incandescent tungsten, has its proper place in set lighting, and the choice of the correct equipment for the work at hand is a part of the cinematographer's individuality.

As an example of placement of carbon arc lamps for black-and-white photography, the cinematographer on the picture *Citizen Kane* used Duarc broadside lamps as the major lighting units on many sets in that picture.

Citizen Kane was a picture of extreme realism and characterization. Unlike most productions, the sets were ceilinged, which made it necessary to do most of the lighting from the floor. Such procedure required lamps with the penetrating power of the carbon arc.

In obtaining unusually great depth of field, apertures of the order of $f/9$, $f/11$, and even $f/16$ were used. This called for lighting units with great illuminating power in comparatively small housings. Duarcs or type *170* carbon arc spotlights were used for this work.

It is recognized that this is an unusual type of picture, and may not be indicative of any trend for future lighting.

R. G. LINDERMAN, *Chairman*

F. E. CARLSON
R. E. FARNHAM
C. W. HANDLEY
D. B. JOY
J. W. BOYLE
K. FREUND
K. STRUSS

DISCUSSION

MR. OFFENHAUSER: What are the name and the type number of the filter used to correct the color-temperature of the lamp referred to in the report?

MR. LINDERMAN:* The filter is the Macbeth Whiterlite filter. It is usually used in the shape of a rondel. Three sizes are furnished, which fit inside the 500-watt, 2000-watt, and 5000-watt Solarspots.

MR. OFFENHAUSER: What is the color-temperature of the lamp used, and to what color-temperature is the source raised through the use of the filter?

MR. LINDERMAN:* The color-temperature of the *CP* (color photography) lens used is rated at 3380°K.

The exposure meter mentioned in the report is the one developed by Captain Don Norwood, described in a paper presented at the 1940 Fall Meeting at Hollywood and published in the April, 1941, JOURNAL (p. 389).

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* Communicated.

ADVENTURES OF A FILM LIBRARY*

RICHARD GRIFFITH**

Summary.—*Collecting and circulating important films of the past is not as dusty an occupation as it sounds. Even the mechanical acts of collecting and preserving film involve the human factors: people feel strongly about works that they themselves have created, criticized, or merely seen, and the collection of films both in this country and in Europe has been fraught with emotional, financial, and political complications, while the number of illustrious personalities who have in one way or another become involved in the Museum of Modern Art Film Library's work is evidence of the ability of even the most ancient fragments of celluloid to retain a contemporary as well as an archaeological interest.*

Circulation of the Film Library's motion picture programs has proved illuminating in its revelation of the attitude taken toward the film medium by all varieties of persons. The purpose has been to provide students with the opportunity to form a critical attitude by examining important films at first hand. There has gradually grown up a new appreciation which has learned not only to marvel at the rapid development of this new medium but also to discern its enormous and largely untapped potentialities.

To "trace, catalog, assemble, exhibit, and circulate a library of film programs"—the stated purpose of the Museum of Modern Art Film Library when it was founded in 1935—sounds like a straightforward enough job. A difficult one, perhaps, and a dead and dusty one to some, though not to the trustees of the Museum of Modern Art and the staff of the infant Film Library, for this department of the Museum was created, in the words of the original announcement, "so that the motion picture may be studied and enjoyed as any other one of the arts is studied and enjoyed." Everyone connected with the Museum and the Film Library expected to enjoy this work of reviving favorite films of the past as much as did the groups of movie enthusiasts throughout the country who have since constituted the Film Library's audience. "Tracing, cataloging, and exhibiting" important pictures seemed about the pleasantest—or one might even say the most glamorous—form of scholarship imaginable, and no one

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** Museum of Modern Art, New York, N. Y.

supposed, at that time, that it could present problems much beyond those to be expected from any scholarly activity.

That was six years ago. Since then the Film Library, with the aid of a grant from the Rockefeller Foundation and gifts of money from private sources, has accumulated sixteen million feet of film: it would take 3000 hours, or 365 eight-hour days, to see it all. During that same period the Library has circulated ninety-one programs of films selected from this collection to 476 museums, colleges, and other educational or non-commercial institutions, some of which have taken virtually everything that the Film Library was able to supply, while others have several times repeated series of programs. The films circulated are all newly made positive prints and the majority of them go out with printed program notes of a critical and descriptive nature for each member of the audience, together with piano music to supply an accompaniment for silent films. Book lists, bibliographies, and information of a scholarly or technical nature have been freely provided not only to users of programs, to journalists and writers, to firms or individuals in the motion picture industry, but to the public generally. The Film Library has in fact become a center of information about all matters pertaining to films. At the same time it has amassed a comprehensive collection of books, periodicals, manuscripts, still photographs, and other materials on the motion picture which is now available for reference without charge to the general public through the Museum Library.

Statistically speaking, this sounds as if the original purpose of the Film Library has been carried through as conceived—as a plain and straightforward museum job. But the statistics fail lamentably to tell the story. The Film Library soon discovered in fact what it had all along believed in theory, that the movie is the liveliest of the arts, and that even the most ancient fragments of celluloid retain a contemporary as well as an archaeological interest. Almost all the Library's activities have been fraught with emotional, financial, and even political complications, and the task of creating this film collection has proved to be a long series of adventures, in which the human element has loomed larger than scholarship or finance.

In 1935, no consistent effort had been made to preserve or present for reëxamination the films of the past through which, step by step, this great and popular art has developed. Almost all the films of historical or aesthetic importance were then invisible and in danger of being lost or destroyed. Under such circumstances, no serious

study of the history and development of the motion picture or of its influence or aesthetic value could be undertaken. The Film Library, therefore, conceived as its first and most immediate task the collection and exhibition of the maximum amount of film.

Here it was, of course, a case of first catch your hare. How were the necessary films to be obtained? It is not widely realized that a motion picture can not usually be bought or otherwise procured as can a book or a painting; or that, even if a print of a film be so obtained, its physical possession does not necessarily entail the right to its use or showing. It is true that in the early days of film history there were many producers, like the Frenchman Georges Melies, who sold prints of their films outright, so that a purchaser could dispose of a copy of, say, *A Trip to the Moon*, exactly as he wished until it wore out. Here were obvious disadvantages. The producer could flood the market with as many prints as he could sell to competing showmen, yet it was generally they who reaped the profits through exhibition, and there was no way of ensuring that the purchaser of a print would not, as he often did, illegally make duplicate negatives from his print and so compete with the producer himself in the sale of still more prints. It is also true that in those early days a successful film continued to be shown for a long period of time (for all we know, *A Trip to the Moon* is even now being shown commercially in Zanzibar or in the Australian interior) instead of, as today, for a mere year or so. But most of the men who made the early films went bankrupt. From a collector's point of view it is fortunate that their methods of business left behind a residue in the form of numbers of prints in private hands or in the vaults of dealers in scrap-film. And so, anomalously, the Film Library often found it easier to acquire very old films than more recent ones.

It proved, in fact, relatively simple to acquire by token purchase, gift, or loan a fair representation of film-making in this country and abroad from 1895 to 1912. Prints of primitives of the art like *The Great Train Robbery* were acquired from the widow of the pioneer Jean A. Leroy. From amateurs, from scrap-film or "junk" firms, from film pioneers or their heirs most of the outstanding early films were obtained. In one instance Mr. William Jamison of the Film Library's staff found a print of *The Execution of Mary Queen of Scots* (much spotted with tobacco juice) in an open garbage can in the Bronx. Another day a total stranger telephoned to offer a film that she had had in her hat-closet for many years.

The situation proved quite otherwise in regard to films of later date. Most of the motion pictures made since 1912–1914 are the property of producer or producer-distributor firms who rent but do not sell prints for commercial exhibition through their own or other distributing companies. Ownership and consequently the right to exhibit such films remains firmly in these hands. Obviously, then, in order to gain access to such material, it was immediately necessary to enlist the sympathetic support of the film industry as a whole. This the Film Library consequently attempted to do. Happily its creation, and the fact of its support by such an institution as the Rockefeller Foundation, had received a "good press"; people generally approved the idea. And, equally happily, among the trustees and friends of the Museum were several who had immediate interests of one sort or another in the motion picture industry.

Armed therefore with auspicious introductions, the director, John E. Abbott, and the curator, Iris Barry (in private life, Mrs. Abbott) shortly after the formation of the Film Library found themselves, to their considerable amazement, in Hollywood about to entertain an alarmingly brilliant concourse of filmdom's great at Pickfair. Certainly the gracious gesture of Mary Pickford in thus throwing open her famous house, and herself acting as hostess, could alone have afforded the infant Film Library so excellent an opportunity of putting its case before the aggregate film chiefs, and through the press, which reported the somewhat unusual event, a wider circle of film employees and the public. That evening, pioneers of the industry like Mack Sennett met newcomers like Walt Disney for the first time, old acquaintances were renewed and new ones made, for Hollywood, contrary to report, is no more gregarious than any other community whose inhabitants work for a living and reside, often, twenty miles apart. For once the exponents of this new art-industry who normally live for the immediate future and the work in hand, stopped the clock briefly to consider the past. They had been, for the most part, brilliantly successful but had often as a consequence faced criticism proportionate to the enormous influence they exercised on the public imagination. Now an outside agency suddenly appeared, asking only permission to preserve a record of their endeavors, and seeking no financial contribution from them—at least not for the moment. The brief program of films given after supper had been selected by the Film Library as an illustration of the work it intended. This glimpse of the birth and growth of an art that was peculiarly

their own both surprised and moved this unique audience. The screen doubtless brought back memories of early struggles and half-forgotten triumphs, of former companions seldom remembered. There was a tiny, shocked gasp at the first appearance of Louis Wolheim in the program's brief excerpt from *All Quiet on the Western Front;* he had been dead so very short a time. Was fame so brief? Of course there ought to be a museum of the film! At the close of the program, Will H. Hays and Mary Pickford endorsed the Film Library's undertaking in enthusiastic speeches. Samuel Goldwyn and Harold Lloyd as well as Miss Pickford promised their films. A major obstacle had been overcome in gaining the attention and understanding of the industry as a whole. It remained to work out a basis on which films owned by large corporations rather than by individual producers could be made available to the Film Library. Its principles had been accepted even if there remained individuals to convert, like the world-famous director who, that same summer of 1935, said amiably but firmly that he, for one, was not interested in the preservation of his own films and that nothing could convince him that films have anything to do with art. It is pleasant to record that he has latterly become a warm supporter of the Film Library's undertakings.

Back in New York, a satisfactory basis of operations was reached after considerable negotiation with the big producer-distributor companies involved, and the Film Library finally obtained the right to the non-commercial use of industry-owned films. This was a signal triumph, for not only could the institutions obtain and use prints of the films it wanted but the propriety of its undertaking had thus been recognized. There were stipulations that bore heavily on some of the institutions desirous of using the programs, but some of these, too, are about to be relaxed, and other problems that arose pertaining to copyrights and the like have been solved as they came up.

There is much misconception regarding the nature of film and its use; the general public is not wholly aware that it is a costly commodity to handle. It is often asked why the Film Library can not purchase "old" film outright. Other considerations aside, this is impossible since the copyright title of almost any film can be resold for, and consequently is worth, many thousands of dollars. The big producer-distributor firms preserve all their negatives but, usually, not prints. Were they to preserve prints that have seen much use, or preserve new prints over a long period of time, they would be

useless for projection in any case. In order to obtain any picture, the Film Library consequently pays the actual cost of making up the new print or prints it requires and of replacing these prints when they wear out. It should be borne in mind that no non-commercial institution could afford to accept a print of each film made, even at no charge—as the Library of Congress acquires copies of all newly published books—because the cost of storage and preservation would be prohibitive. The Film Library can only select.

Here arises a question: what shall be selected either for preservation and research or for circulation to the wider circle of film students? Little doubt arises in the case of greatly famous films like *The Birth of a Nation*, *The Cabinet of Dr. Caligari*, *The Four Horsemen of the Apocalypse*, *Potemkin*, *The Jazz Singer*. Though these may seem quaintly archaic or regrettably controversial, nevertheless they are "musts." But what of others that, because of their extreme popularity at one time, or because they incorporated a technical or aesthetic innovation, or celebrated a social or political trend, might be needed in a well rounded collection. Take the case of Will Rogers' *The Headless Horseman*, first feature-film on panchromatic stock. Or the brief *Peace of Britain*, which urged the case against war. Or *The Andalusian Dog*, without which no study of surrealism or the work of Salvador Dali would be complete. It would be difficult to view the Rogers film without boredom, while some proportion of any general audience would doubtless feel indignation upon viewing *The Peace of Britain* and considerable shock upon seeing *The Andalusian Dog*. Boring or tendentious books may go on a library shelf; paintings that provoke strong reactions may be hung publicly without excessive odium. The exhibition of a film has not yet become so liberal an undertaking. Individuals violently protest against the spectacle of films that for any reason displease them: custom seems to have entailed upon the showing of films a peculiar moral responsibility. The seeing of films is of course a mass experience, not a private one like the reading of a book or the viewing of a painting, which may explain much. And perhaps it is felt that with this new medium of expression, as with the printed word long years ago when it too first arrived to extend the public experience, there is some special if mysterious danger. After all, films *do* convey ideas!

This is by no means the only problem that the collection and revival of films creates. Suppose there is a widespread opinion backed up by recollection and hearsay or by written criticism that a film such

as Lubitsch's *The Marriage Circle* should definitely be included and shown. To the layman the solution might seem easy: one has only to look and see whether it survives the test of time. But before a film of that age can be looked at, a print must be made up and paid for—and a $250 look proves costly indeed should the film turn out to be of restricted interest. More than that, it will cost $10 a year thereafter to keep the print in storage if one elects to wait and see whether, with the passage of still more time, the change of taste and outlook may show this judgment a misguided one—as in the other arts many such judgments have been. In truth there can be few materials subject to scholarship and preservation that present more difficulties than do motion pictures. A mischievous muse presided at their birth.

So in gathering together important but long unseen films of the past the Film Library staff, somewhat like Whistler, has had to rely "on the experience of a lifetime." Its own aggregate experience includes that of its dean, William Jamison (who has been in the industry since its birth and is rumored to be able to tell who made a film merely by feeling it between his fingers in the dark) and of associates like the ace cameraman "Billy" Bitzer, or particular friends in and outside the industry like Terry Ramsaye, Louis Bonn, or W. S. Van Dyke. There is also the valuable consensus of the public to draw upon: everyone agrees that the first Mickey Mouse and *It Happened One Night* are proper museum pieces, and everyone wonders why on earth the Film Library does not have *Quo Vadis* and *The Blue Angel.*

First catch your hare! When two comprehensive series of programs tracing the development of the American film were already in circulation, the director and the curator undertook a protracted trip in the summer of 1936 to London and Paris and thence to Berlin, Warsaw, Moscow, Helsingfors, Stockholm. The results were fruitful and sometimes quite unexpected. To begin with, the idea of collecting and preserving film was already not novel in Europe. Film archives—of very different kinds but nevertheless archives—had already been started in Paris (privately or at best with semi-official blessing and virtually no funds), in London (semi-officially and with some but inadequate funds for preservation as opposed to collection), in Berlin (officially and with apparently ample funds, with emphasis on preservation but still more on the collection of propaganda films, preferably anti-German), in Moscow (officially but apparently with little regard for preservation), and in Stockholm

(under ideal conditions but for Swedish films only). The emissaries of the Film Library were eagerly shown vaults of film, asked whether some exchange basis might be arrived at, or whether, if the threat of war came closer, New York might undertake to store precious prints or negatives. Paris was particularly sensitive to war risk: between 1914 and 1918 far too much historic French film had been junked to provide the nitroglycerine to which celluloid is chemically akin. The warmest understanding was found in France, and much film was acquired. In Berlin it was Olympics year and tourists were particularly welcome. It was a relief to find that, contrary to rumor, the films of Germany's great silent period 1919–1928 had not been destroyed, so that the Film Library was able to obtain virtually everything it desired, from *The Cabinet of Dr. Caligari* down to a brutal but most illuminating Nazi-inspired feature of 1934. Moreover, from the official Reichsfilmarchiv came *Potemkin*, most famous of Russian propaganda films, the original negative of which Dr. Goebbels had purchased in 1933, pointing to it as a model for Nazi propagandists to emulate.

For some reason that the director and curator never quite fathomed, the sailing was less smooth in Moscow. It may merely have been that they represented an institution supported by private contributions and not by government funds. Certainly film directors and students were friendly and eagerly interested, but officialdom, through whom alone any film could be obtained, at first refused all occasions for presenting any request. Finally, with the strenuous help of the U. S. embassy, a hearing was obtained and the reluctant or suspicious atmosphere was somewhat overcome. A basis for exchange of film between the Scientific Research Institute's collection was finally arrived at, and late in 1936 four films finally arrived in New York from the U.S.S.R. But none really representative of the new régime arrived until the late summer of 1939 after little hope remained of receiving even an acknowledgment of the films the Library had dispatched to the Institute. When they did arrive it was at a moment when, to put it mildly, recent political events had created a marked apathy toward Russian films, no matter how interesting they might be from a technical or ideological viewpoint. Nor was there much but apathy or distaste for films of comparable nature from contemporary Germany, such as the propagandist documentary of 1937, *Flieger, Funker, Kanoniere*, in which Field Marshal Goering in person commended the effort that gave Germany an air force, while the

film itself showed a glimpse of dive-bombing and introduced the now-familiar term *Luftwaffe*. It was nevertheless a shadowy image of what was to come both in fact and in later documentaries like *Feldzug in Polen* and *Sieg im Westen*. Recent events have led to a wide recognition of the use and value of studying propaganda material. But at that time the acquisition of foreign material of this kind gave rise to a whispering campaign (originating, it seemed, among small groups of film enthusiasts with axes to grind) that the Film Library, or the Museum as a whole, or perhaps even the Board of Trustees (!) was infiltrated with Nazi principles (this was in 1937 and 1938) or with Communist principles (this was in 1940) or at best with some "un-American" spirit.

Meanwhile the Film Library has restored to view, to admiration, and to their proper standing among other contemporary works of art, a great wealth of American films. It pointed out (what is perhaps obvious) that while France at first, then Italy, then Germany contributed both styles and film-makers to the growing American film industry, the motion picture as such is triumphantly and predominantly an American expression. It was this American development, the Film Library stated, that in turn signally stimulated film-making in France, in the U.S.S.R., and indeed the world over by its technical inventiveness, its energetic and impulsive grasp of the medium. If the little campaign of slander persisted longer, it received small credence. Meanwhile in 1938, when at the invitation of the French government the Museum of Modern Art put on exhibition "Three Centuries of Art in the United States" at the Musée du Jeu de Paume in Paris, the section prepared by the Film Library was the most widely attended and, with the architectural section, the most enthusiastically received of all the comprehensive show. In films the United States was seen at its most original, most exuberant, most enjoyable, most understandable. And in presenting its "Brief History of the American Film" there, as in all its numerous programs circulated at home, the Film Library affirmed its unwavering faith in the film as the liveliest as well as the most popular of the contemporary arts and one in which the United States is supreme.

Public education and guidance in film appreciation have been so slow to develop, however, that people sometimes complain that they do not "like" all the films shown, forgetting that these are not shown as diversion or entertainment but for the pleasures of comparison, analysis, and study. A few make a small nuisance of themselves by

rather ostentatiously tittering at the outmoded dresses, obsolete slang, old-fashioned moral values of films ten or twenty years ago. This, it must be said, is habit fostered by certain sections of the film industry itself through the revamping of "old" films to turn them into ridicule. But it is interesting to observe that films which are *old enough* do not provoke that reaction. It is very evident, too, that laughter at the death of Camille, played most expertly though in an obsolete style by Sarah Bernhardt, or at the dresses of Greta Garbo in *Susan Lennox*, is fraught with shock at the sudden disruption of the time sense rather than with merriment. As audiences gain the habit of looking at films as something more than a transient distraction, the tendency to ridicule diminishes noticeably, but its existence suggests some curious conclusions on the impermanence of standards of taste.

Aware of all these and other difficulties and criticism it has faced and must expect, the Film Library has prepared for exhibition a very large proportion of its collection in the current retrospective of motion picture history, "A Cycle of 300 Films, 1895–1940," which now is showing daily in the Museum's auditorium, and which contains the cream of the Library's collection so far. No such experience has ever been afforded to the students and enthusiasts in any art, let alone in the art of the motion picture. That it is possible at all after so few years of activity in this new field is due largely to the continued enthusiasm and support of the Museum trustees, of the representatives of the motion picture industry on its Advisory Board, and of those amateurs of cinematography who attend its showings.

There are some notable absences in the cycle. Where, for instance, is *Quo Vadis*, epic costume film of 1911 from Italy, which played so signal a part in introducing longer pictures and in making the movies respectable? The most patient search and inquiry has brought no trace of it thus far. *Morocco* is here but not the well-remembered *Blue Angel*, in which husky-voiced Marlene Dietrich broke like a new comet on our world. Owned originally by one of the big American firms for distribution in this country, the rights had reverted to the German producer-firm, Ufa. This was one film asked for in Berlin in 1936 that Nazi officialdom refused even though, surprisingly, they authorized the acquisition of numerous other films made by non-Aryans and anti-Nazis, most of whom now swell Hollywood's rank of talent. What about *The Exploits of Elaine*, which "everybody" remembers as having been so incomparably breath-taking? This

was acquired, *via* Paris, from Brussels where someone had tracked down a series of episodes which were purchased for 1000 francs. The prints on arrival proved in such bad condition, so brittle and with so many sprocket-holes broken, that a duplicate negative of one reel was made up for tentative inspection before venturing to "dupe" the whole eight episodes. Never was there a sadder little group of film fans than the staff of the Film Library upon viewing that trial restoration of one of the great legendary "musts" of film history. Hopefully, another episode was printed: it seemed a *little* better, but unless further inspection of further episodes brings higher quality, then *Elaine* must join the few other overrated "gems of the past."

Unfortunately lacking are many of the Mack Sennett comedies of the vintage period. Inquiry has proved that, not so very long ago, the original negatives of these films were cut up to be remade into talkies. All was lost in this case. Regrettably, the old John Bunny and Flora Finch comedies proved disappointing, rather flat and unfunny: perhaps others will be found that will revive memories of childhood enjoyment long years ago.

And where, especially, are the Charlie Chaplins? True, there are a few here in the cycle, early and delicious, but so few. Others, slightly later and still better, which were shown earlier at the Museum, are no longer visible. These unhappily must remain in the vaults, for they may no longer be shown—at least for the time being. As suggested earlier, the Film Library is the custodian, not the owner of its films, and the owners may require it to desist from exhibition at any time. This happens when pictures in the collection are revived for commercial exhibition. It seems hard, especially in cases where it is reasonable to suppose that interest in them was first recreated by the Film Library's revival of them. As for the later and greater Chaplin comedies, these belong to the comedian himself, and so far he has not seen his way to turning them over.

Meantime, with exceptions as noted, the Film Library has continued to fulfill its original purpose and has further extended its program. In its newest phase of activity, it houses a project under the Office of the Coördinator of Cultural and Commercial Relations between the American Republics for the provision of educational and documentary films in Spanish and Portuguese to the twenty sister nations of the hemisphere. With the growing recognition of the film as a major social and cultural force in our time the Film Library's horizon becomes unlimited.

WORK SIMPLIFICATION—ESSENTIAL TO DEFENSE*

ALLAN H. MOGENSEN**

Summary.—*Increasing productivity is the most important job today. It will not be done by "speeding up." Work simplification, using motion pictures as the main tool, helps everyone in an organization to find "the one best way." Applications of the motion picture in such studies are described in the paper, as also a specially designed projector for exhibiting the pictures.*

The most serious problem facing America today is that of increasing our industrial productivity. No matter how much money we spend, no matter how much floor space we add to our plants, no matter how many machines we eventually are able to build, we are nevertheless limited by the number of possible man-hours. And when one analyzes the figures of the new plans and schedules, it is immediately apparent that unless something is done to increase productivity we shall not be able to increase our production to the point where it will be of real value in winning the war.

Few people understand the difference between increasing production and increasing productivity. So far we have gone largely on the assumption that if we want to turn out twice as much product, we merely have to double the floor-space, buy twice as many machines, and hire twice as many men. Temporarily the question as to where the money is coming from does not bother us, but it most certainly will if the effort is continued over a period of several years. Up to the present, floor-space has not been a serious handicap as one can readily see from the sizes of the aircraft and other plants that are being put up all over the country. However, we are now reaching the point where shortage of building material may be a critical factor. Securing adequate productive machinery has been a problem all through the defense effort, and would be an increasingly serious one if the program is multiplied in its scope.

Man-power, on the other hand, has been a serious problem from

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the start, although taking up the slack of unemployment and then robbing skilled men from other "less important" industries has so far seen us through the preliminaries. It soon became evident, however, that it would be necessary to train many of the unskilled people for skilled jobs, and to induct into unskilled jobs many who have never worked before. Witness the effort of many of the fine men who have been called from industry to come to Washington to assist in setting up training programs and in developing the "up-grading" plans that have produced results.

All this, however, is overlooking the most obvious truth of all, and that is that if we are to increase output we must increase productivity, that is, we must increase the efficiency of every unit in our production scheme. If a man can produce twice as much with the same equipment, floor-space, and in the same number of hours, and yet go home less tired than he was before, something has been accomplished toward finding a solution to a problem that has puzzled so many people. Notice I say in the same number of hours. In the last war England tried very long working hours in an effort to increase output. Studies made by the National Institute of Industrial Psychology proved conclusively that output fell off rather than increased, and therefore the number of hours was reduced. Despite this lesson learned both abroad and here during the last war, England has again attempted, and we are now attempting, to increase our output by going to excessive overtime.

What is the answer? Work simplification, taught to every single member of an organization and taught by the use of motion pictures, is the answer.

Very few persons understand the difference between work done at high speed and work done in a hurry. Most of the attempts made so far at increasing our output have been to "speed up" production. Work done at high speed will give good results because it is accomplished by eliminating unnecessary parts of the job; whereas work done in a hurry will be unsatisfactory because it includes speeding up both necessary and unnecessary parts of the job. One can not blame the workman for not understanding this fundamental fact when very few of our chief executives appreciate its truth. Therefore, instead of trying to get a man to work harder or faster, work simplification seeks to find the "one best way" of doing each job. This way is usually the easiest way and, in fact, is often so simple that one wonders "why we did not think of that before."

The motion picture is used in two ways in connection with work simplification programs. The first and most obvious form is the "before and after" picture to teach fundamentals to all concerned. Such films show the former way of doing a simple operation, and then demonstrate the new and easier way of performing it. Each of the films illustrates a fundamental principle in work simplification or motion study, and then enables the person who has seen the film to analyze his own operations and apply the principle to simplifying them.

(Mr. Mogensen then showed a film on a simple operation in a garment plant demonstrating how the output of a unit was tripled by analyzing the motions that went into the performance of this operation. Part of the increase was due to the elimination of seventy-four useless motions formerly included, and part was due to the fact that the new method was so much simpler that it was possible for the girls to develop much higher skill than previously. Also, many more girls could become really skilled operators under the new method, whereas only a few could become skillful under the previous method. Redesign of the work-place, study of the tools used, and operator training were demonstrated in the picture.)

The use of the motion picture in this way is, of course, not new. One application that has been extremely successful, especially in some of the new defense plants, is the use of a film-loop for training operators. The idea of the film-loop used for training is not new. Frank B. Gilbreth applied it at least twenty years ago, and the speaker has used it in connection with training programs since 1926. However, proper equipment for the most effective use of this tool has not been available until recently. A special version of a commercial 16-mm projector has been designed by Prof. David B. Porter, of New York University, and has been used in almost every conceivable kind of industry and business by graduates of the work simplification conferences held each year at Lake Placid Club.

The use of the equipment can be illustrated by describing the procedure used in training operators in a new defense plant recently set up in the Middle West. First, the operation as it was performed at one of the U. S. arsenals was photographed completely from start to finish on 16-mm film. The picture ran about 4000 feet when edited and titled. A small group of engineers then looked at the film, and of each operation asked, "Why?" "Is there a better way?"

Analysis of the film occupied the time of the new plant manager and an industrial engineer for about a week; at the end of this time it became evident that the specifications set forth by the government

demanded about twice the equipment that was actually necessary. It was shown that the new plant could be erected with about half the floor-space called for in the government specifications, and that only about half the number of operators would be required. It can be seen, of course, that this greatly simplified the problem of procuring machinery, as well as that of training operators.

As each new employee was brought into the plant, he or she was shown the picture in its form at that moment and told that the procedure depicted was not necessarily the best way to make the product, but that it was the best way known at that time. Each employee was told that he or she would undoubtedly have many good suggestions for simplifying the operations and were urged to ask "Why?" at every step. Aptitude tests, followed by a medical examination, then determined whether or not the applicant was suitable for the job for which he or she was being considered.

When the operator was finally selected for the job, he (or she) was taken into the training room and the particular loop of film covering the operation was projected on the screen. The film was run slowly at first, and all the requirements as to quality of product, safety, and output were explained. Usually several loops covered an operation. First, the new employee would be shown a long shot demonstrating the overall handling of the equipment, the procurement of the material, and general safety factors surrounding the operation. Then successive close-ups were shown, and every conceivable feature of the operation was demonstrated and explained by the instructor.

Following the instruction with the film-loop, the operator was introduced to the foreman or forelady on the job and the actual training was begun. Successive visits to the classroom were included as the training progressed so that the correct procedures could be constantly emphasized. Very often in the past instruction cards or write-ups of the correct methods have been given to new operators, but no attempt has been made to see that the operators actually followed the designated motions during the training period. Bad habits creep in, and while often they are small and may appear insignificant, they spell the whole difference between a smooth, efficient, and restful operation as against the nervous drive so often seen behind attempts to get operators to increase their output.

One of the very important advantages of the special projector is that one does not have to take all the pictures at 64 frames a second in order to slow down the motion. The biggest objection to slow

motion in the past has been the expense of filming everything at that speed. Very often only a small part of the resulting film was needed in slow motion and the cost was therefore prohibitive. With this machine everything can be taken at 16 frames a second, and the slow-motion effect secured in almost all instances except where very rapid hand motions do cause some blur when the still picture is projected on the screen.

For actual motion analysis two new features have greatly simplified the determination of time from the film. In the days of Gilbreth's first work the timing device was a spring-driven "microchronometer," later replaced by a Telechron motor. The latest development is a small device that eliminates the necessity of reading a dial inasmuch as it is built on the cyclometer principle. It is produced by Veeder-Root, Inc., and is known as the "Wink Counter."

Where it is not desirable to include the clock in the film, one may take the picture with a constant-speed camera driven by a synchronous motor, and then the special projector demonstrated here is equipped with a small frame-counter so that time may be taken directly from the film. A heat-absorbing filter allows lengthy study of each frame, if desired, without warping the film. There are many 16-mm projectors on the market that are satisfactory for home projection of an occasional frame, but none of them allows detailed frame-by-frame analysis of the type desired by the motion study engineer. The 16-mm motion picture film provides the only effective means of making micromotion studies where high production work warrants the cost of such analysis.

Motion picture films are absolutely essential if the principles of work simplification are to be applied to the job of increasing productivity. First of all, it trains the organization in finding easier and better ways of doing their jobs. It helps to break down the traditions that so often dictate methods that are used largely because "we have always done it that way." The film loop has proved its value in enough instances to convince those who have used it that training time can be greatly reduced. An operator who is not suited for a particular job can be transferred to other work before a long period of discouragement and dissatisfaction is encountered. Supervisory and executive time is definitely reduced. Operators rapidly attain the required skill and thus fall into the high earning classes. Finally, this method of training will eliminate the need for much of the expensive equipment that was formerly tied up in the "vestibule school" method of training.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C., at prevailing rates.

Acoustical Society of America, Journal

13 (January, 1942), No. 3

Performance of Broadcast Studios Designed with Convex Surfaces of Plywood (pp. 244–247)	C. P. Boner
Acoustic Impedance of Porous Materials (pp. 248–260)	L. L. Beranek
An Acoustic Tube for Measuring the Sound Absorption Coefficients of Small Samples (pp. 261–264)	D. P. Loye and R. L. Morgan
Properties of the Dulled Lacquer Cutting Stylus (pp. 265–273)	C. J. LeBel
A Large Radius Stylus for the Reproduction of Lateral Cut Phonograph Records (pp. 274–275)	J. D. Reid
Tracing Distortion in the Reproduction of Constant Amplitude Recordings (pp. 276–280)	L. W. Sepmeyer
A Noise and Wear Reducing Phonograph Reproducer with Controlled Response (pp. 281–283)	F. H. Goldsmith
The Correlation between Elastic Deformation and Vertical Forces in Lateral Recording (pp. 284–287)	S. J. Begun and T. E. Lynch
The Recording Laboratory in the Library of Congress (pp. 288–293)	J. B. Wiesner

Educational Screen

21 (January, 1942), No. 1

Motion Pictures—Not for Theaters (pp. 14–17, 21), Pt. 33	A. E. Krows

Electronic Engineering

14 (January, 1942), No. 167

Television Picture Storage (pp. 578–580, 600)	A. H. Rosenthal
Frequency Modulation (pp. 584–585, 600), Pt. III	K. R. Sturley

Secondary Electron Problems in Beam Tetrodes (pp. 586–587) — J. H. OWEN HARRIES

Electronics

15 (January, 1942), No. 1

Super-Cardioid Directional Microphone (pp. 31–33, 91–93) — B. B. BAUER

International Photographer

14 (February, 1942), No. 1

Ninety Below (pp. 3–4)

Government Training Films (pp. 8, 16)

International Projectionist

16 (November, 1941), No. 11

Some Improved Methods of Controlling Carbon Arc Position (pp. 9–10, 12–13, 23) — D. J. ZAFFARANO, W. W. LOZIER, AND D. B. JOY

Projection Room Routine under Normal and Emergency Operation (pp. 15–16) — H. RUBIN

New Photographic Lens Wins Trade Press Approval—But I. P. Dissents (p. 19)

RCA Review

6 (January, 1942), No. 3

NBC Studios 6A and 6B (pp. 259–268) — G. M. NIXON

A New Chemical Method of Reducing the Reflectance of Glass (pp. 287–301) — F. H. NICOLL

FIFTY-FIRST SEMI-ANNUAL CONVENTION

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TENTATIVE PROGRAM

MONDAY, MAY 4, 1942

9:00 a.m. *Hotel Lobby;* **Registration**
12:30 p.m. *Terrace Room;* **Informal Get-Together Luncheon**
Addresses by prominent Hollywood members of the motion picture industry; names to be announced later
2:00 *Blossom Room;* **General Session**
8:00 *Blossom Room;* **Technical Session**

TUESDAY, MAY 5, 1942

9:30 a.m. *Hotel Lobby;* **Registration**
This morning will be left open for a possible trip or other activity to be announced later
2:00 p.m. *Blossom Room;* **Technical Session**
8:00 *Blossom Room;* **Technical Session**

WEDNESDAY, MAY 6, 1942

9:30 a.m. *Hotel Lobby;* **Registration**
10:00 *Blossom Room;* **Technical Session**
2:00 p.m. The afternoon will be left open for a possible trip, to be announced later, or for recreation
8:30 *Blossom Room;* **Fifty-First Semi-Annual Banquet and Dance;** details to be announced later

THURSDAY, MAY 7, 1942

10:30 a.m. *Hotel Lobby;* **Registration**
Open morning
2:00 p.m. *Blossom Room;* **Technical Session**
8:00 *Blossom Room;* **Technical Session**

FRIDAY, MAY 8, 1942

10:00 a.m. *Blossom Room;* **Technical Session**
2:00 p.m. *Blossom Room;* **Technical Session**
8:00 *Blossom Room;* **Technical Session**

Adjournment of the Convention

HEADQUARTERS

The Convention headquarters will be at the Hollywood-Roosevelt Hotel. Excellent accommodations have been assured by the hotel management at the following *per diem* rates:

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Two persons, double bed and bath	5.00
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Parlor suite and bath, one person	8.00–14.00
Parlor suite and bath, two persons	12.00–16.00

Room reservation cards will be mailed to the membership early in April and should be returned to the hotel immediately to be assured of satisfactory accommodations.

Indoor and outdoor parking facilities adjacent to the hotel will be available for those who motor to the Convention.

Golfing privileges may be arranged by request of the hotel management or at the registration headquarters.

Registration headquarters will be in the hotel lobby. All members and guests attending the Convention will be expected to register and receive their Convention badges. The registration fees are used to defray the expenses of the Convention, and coöperation in this respect is requested. Identification cards will be supplied, which will serve as admittance to all scheduled or special sessions, studio visits, and trips, and several *de luxe* motion picture theaters on Hollywood Boulevard in the vicinity of the hotel.

Members planning to attend the Convention should consult their local railroad passenger agents regarding train schedules, rates, and stop-over privileges *en route*. For a stop-over at San Francisco the Convention Committee recommends the Mark Hopkins Hotel, on "Nob Hill." Accommodations may be arranged with Mr. George D. Smith, manager of this hotel.

An interesting color-print exhibit will be an adjunct to the Convention and will be open to the public and delegates during the five days of the Convention.

The Convention hostesses promise an interesting program of entertainment for the visiting ladies. A reception parlor will be provided as their headquarters at the hotel.

Note: The Pacific Coast Section officers and managers gave serious consideration to the question of holding the 1942 Spring Convention at Hollywood, and have decided to proceed with arrangements for the meeting. The motion picture industry plays an essential part from the exhibiting and engineering viewpoint in upholding the morale of the general and theater-going public in the present crisis, and accordingly the Convention and Local Arrangements Committees are porceeding with their plans. However, if later deemed advisable in the National interest, the Convention will be subject to cancellation thirty days prior to the announced Convention dates.

W. C. KUNZMANN,
Convention Vice-President

BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted.

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Beginning with the January 1930, issue, the JOURNAL of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers of all issues are available at the price of $1.00 each, a complete yearly issue totalling $12.00. Single copies of the current issue may be obtained for $1.00 each. Orders for back numbers of *Transactions* and JOURNALS should be placed through the General Office of the Society and should be accompanied by check or money-order.

SOCIETY SUPPLIES

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Motion Picture Standards.—Reprints of the *American Standards and Recommended Practices* as published in the March, 1941, issue of the JOURNAL; 50 cents each.

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

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

Test-Films.—See advertisement in this issue of the JOURNAL.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

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CONTENTS

Color Television P. C. GOLDMARK, J. N. DYER, E. R. PIORE, AND J. M. HOLLYWOOD 311

New Stop Bath and Fixing Bath Formulas and Methods for Their Revival J. I. CRABTREE, L. E. MUEHLER, AND H. D. RUSSELL 353

Book Review 373

Officers and Governors of the Society 374

Committees of the Society 377

Constitution and By-Laws of the Society 382

Fifty-First Semi-Annual Convention, Hollywood, Calif., May 4–8, 1942 393

Society Announcements 397

(*The Society is not responsible for statements of authors.*)

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COLOR TELEVISION*

P. C. GOLDMARK, J. N. DYER, E. R. PIORE, AND J. M. HOLLYWOOD**

Summary.—*A brief history of color television and the reasons leading up to the CBS Color Television System are presented, and a general theory for color television, including color, flicker, and electrical characteristics is also given.*

Equipment for color television transmission and reception has been designed and constructed based on these principles.

INTRODUCTION

Much of the significance of color in television is striking even to the casual observer. Aside from the most obvious effect, namely, that color introduces a sense of reality and a lifelike quality into the picture, comparison of a color television picture with the corresponding black-and-white image makes it apparent that not only are small objects more perceptible but outlines in general seem to be more clearly defined. As has been experienced with other media, color in television also seems to introduce a certain perception of depth. This is partly due to the increased ability of color to reproduce the contrasts and shadows as well as highlights and reflections in different hues, while the degree of color saturation, which is a function of distance, especially outdoors, strongly enhances the three-dimensional quality.

Effects such as those mentioned here became apparent immediately after initial experimentation with color television and were encouraging enough to warrant an extensive investigation of that field with the objective of producing a practicable color television system.

At the outset it was realized that the transmission and reception of live objects as well as motion picture film in natural color entailed the use of a trichromatic system.

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* Presented at the 1941 Fall Meeting at New York, N. Y., and at the New York Meeting of the Institute of Radio Engineers, October 3, 1941; received October 3, 1941.

** Columbia Broadcasting System, New York, N. Y.

HISTORY

Before proceeding further a brief summary of color television developments in the past will be presented. In view of the large number of proposals for color television systems, only those are mentioned which to the knowledge of the authors have been demonstrated.

A complete color television bibliography, which is almost identical to that compiled by Panel 1 of the National Television System Committee, is appended to this paper.

Color television was demonstrated for the first time in July, 1928, by John L. Baird in England. Both at transmitter and receiver a three-spiral scanning disk was employed. Each of these spirals consisted of a succession of holes which were covered with red, green, or blue filters, scanning the picture completely in the three primary colors. At the transmitter photocells were employed, while at the receiver two gas-discharge tubes controlled by a commutator were used. One of the tubes was filled with neon and acted on the red spiral, while the other tube, filled with a mixture of helium and mercury vapor, appeared through the blue and green spirals. The transmission employed a band width of the order of 10 kc and the pictures corresponded to a number of lines somewhere between 20 to 30 per frame.[1]

In July, 1929, the Bell Telephone Laboratories in New York demonstrated a three-color television system employing three independent channels. The live pick-up equipment consisted of three banks of cells with the three primary color responses. A flying spot scanned the object and a scanning disk served on the receiving end to reconstitute the image. Three discharge tubes furnishing red, green, and blue light and superimposed by mirrors behind the scanning disk served as the light-source.[2]

It is interesting to note that while the Bell Laboratories employed a three-channel system which obviously occupies three times the frequency spectrum over the corresponding black-and-white picture and requires three times the facilities, Baird, though similarly requiring three times the frequency space, employed rotating filters and was thus the first to demonstrate the sequential, additive method of color in television.

Early in 1938 John L. Baird in England demonstrated a 9 × 12-ft, 120-line color television picture using sixfold interlacing, employing a flying spot, mirror drum, and rotating filters at the transmitter. At the receiving end also a mirror drum was employed, rotating at the

rate of 6000 rpm and using a Kerr cell as modulator in conjunction with rotating color-filter slots.

In July, 1939, a demonstration with similar transmitting equipment was reported.[3] At the receiver there was a projection cathode-ray tube combined with a rotating color-filter. The system was a two-color system using alternately orange and blue-green filters. The color picture frequency was $16^2/_3$ per second employing 102 lines.

Finally, on August 28, 1940, a three-color, high-definition television system employing electronic scanning both at the transmitter and at the receiver was broadcast for the first time over Station *W2XAB* in New York City. The subject of transmission was motion picture color-film. Soon after, live pick-up employing the same trichromatic system was demonstrated.

This paper will deal largely with the color television system demonstrated on those two occasions, as well as its subsequent development up to the summer of 1941. Beginning June 1, 1941, daily color transmissions over Station *WCBW* of the Columbia Broadcasting System inaugurated a field-test period for the purpose of determining the practicability of color television as presented in this paper.

CBS COLOR TELEVISION

At the outset of research activities in color television a number of conditions were set down upon fulfillment of which depended the success of practicable color television. These were:

(*1*) For a given band-width the loss in monochromatic definition due to the introduction of color should not be excessive.

(*2*) The system should be based upon three primary colors.

(*3*) Within any given band-width the performance of the color system decided upon should give at least as much satisfaction as the corresponding black-and-white system.

In the color television system under discussion the following terms will be used:

Color-Field Frequency.—The highest vertical scanning frequency employed in the system.

Color-Frame Frequency.—Color repetition time per second, *i. e.*, trichromatic repetition rate per second, corresponding to the color field frequency divided by three.

Color-Picture Frequency.—Number per second of the coincidence of one and the same primary color with one and the same area of the image.

Frame Frequency.—Identical to term used in monochromatic television, *i. e.*, completion of the scanning of the entire picture area per second in black and white.

Before the choice for a final system was narrowed down, several alternatives were considered. These all had in common sequential, additive color scanning where the primary color impulses of varying ratio, following in rapid succession, are integrated by the observer's eyes. The three primary colors employed were red, blue, and green, the characteristics of which will be discussed later. Rotating color disks or drums in front of the pick-up device and the receiving tube, suitably synchronized and phased, produced the color analysis at the transmitter and the synthesis at the receiver.

The various systems combining different interlace ratios, color-fields, color-frame, and color-picture frequencies as well as lines are tabulated in Table I.

TABLE I

Characteristics of Various Systems

System	*1*	*2*	*3*	*4*	*5*
Color-fields (*c*)	60	120	120	180	120
Color-frames	20	40	40	60	40
Frames (*f*)	30	120	60	45	30
Color-pictures	10	40	20	15	10
Interlace ratio (*c*/*f*)	2 : 1	1 : 1	2 : 1	4 : 1	4 : 1
Lines per frame, corresponding to 441 black-and-white, nearest practical value	441	240	315	350	441
Horizontal (line) frequency	13,230	28,800	18,900	15,750	13,230
Lines per frame, corresponding to 525 black-and-white, nearest practical value	525	260	375	450	525
Horizontal (line) frequency	15,750	51,200	22,500	20,250	15,750
Color break-up conditions	Unsatis	Satis	Satis	Satis	Satis
Interline flicker conditions	Unsatis	Satis	Satis	Doubtful	Unsatis
Picture flicker conditions	Unsatis	Satis	Satis	Satis	Satis

System *1*, as can be seen, is a straight adaptation of the black-and-white standards. Though the monochromatic definition was unimpaired, the resulting flicker due to the low color-frame frequency (20) was intolerable even at low illumination values. The effect, known as "color break-up," which is purely a physiological one and increases with decreasing color-frame frequency, was objectionable. A white object which moved across the screen with sufficient velocity

would show red, blue, and green color fringes. Only empirically could it be determined at which color-frame frequency the color break-up for the most commonly transmitted objects in motion became negligible.

In System *1* the color-picture frequency is 10, which gives rise to interline flicker. It will be obvious when considering the subsequent systems that for a constant frame-frequency the color-picture frequency also remains the same. This is an important factor when considering interlace ratios higher than 2.

System *2* employs sequential scanning in order to eliminate interline flicker. The same frequency is 120, and thus the color-field frequency becomes 40 per second. Flicker and color break-up conditions are satisfactory. However, the loss in definition is excessive.

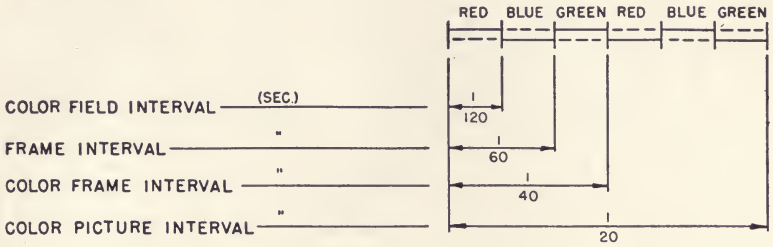

FIG. 1. Diagrammatic representation of CBS System *3*.

It became evident that in order to increase definition interlacing had to be introduced. This led to a system having a color-field frequency of 120, a color-frame frequency of 60, and color-picture frequency of 20 per second. Due to a 2 : 1 interlace ratio the frame-frequency remains at 60 per second and the number of lines at 343. This system gave freedom from flicker with screen brilliancies up to 2 apparent foot-candles and showed no interline flicker. It was subsequently chosen as the most satisfactory compromise for the present 6-Mc band at the same time increasing the number of lines to 375 which corresponds to the 525 lines used in monochromatic television.

System *4* is a compromise between Systems *3* and *5* inasmuch as the color-picture frequency is 15 with a corresponding color-frame frequency of 60 and color-field frequency of 180 per second. The frame-frequency of 45 per second will permit a number of lines approximating $525\sqrt{30/45}$. In this system flicker even at the highest

brilliancies is eliminated; however, the interline flicker still appears somewhat excessive.

System *5* uses the same horizontal scanning frequency as monochromatic television; however, it utilizes quadruple interlacing to increase the field-frequency to 120 per second. Thus flicker conditions are satisfactory and resolution is excellent. However, due to the low color-picture frequency (10 per second) interline flicker appears excessive.

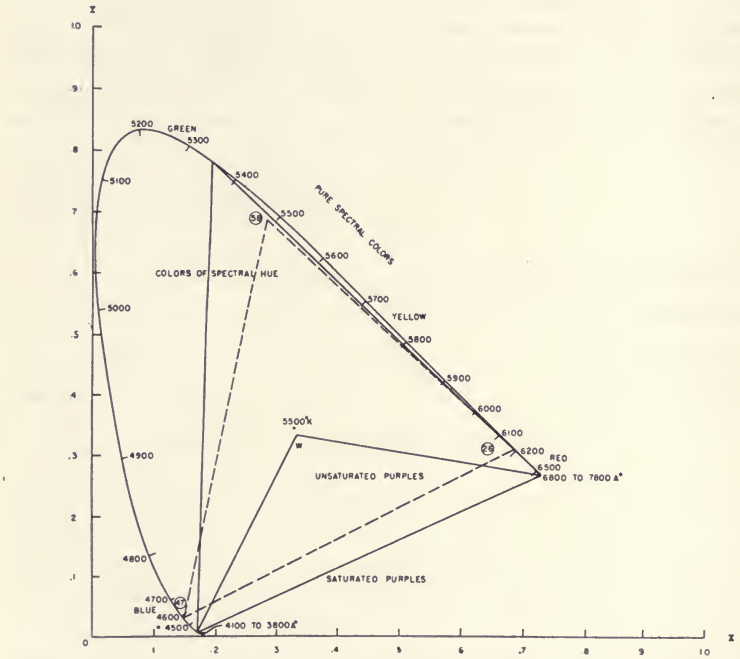

FIG. 2. Unified trichromatic coefficient diagram (color triangle).

In order to avoid the so-called "line crawling" effect the quadruple interlacing in Systems *4* and *5* is of the staggered type where the sequence of lines is 1, 3, 2, 4 instead of 1, 2, 3, 4.

Conditions in these two systems are aggravated by the fact that the color-field frequency of, respectively, 180 and 120 per second, being a multiple of the power-supply frequency, would show a distinct breakdown of the line-structure emphasizing a raster of approximately 100 lines in case 60-cycle components were not completely eliminated from the vertical scanning.

The final decision in favor of System *3*, with System *4* as a close second, had to be made in view of the discouraging results, confirmed by other experimenters, in attempting to reach a satisfactory solution of the quadruple interlacing problem in general.

In Systems *1*, *3*, *4*, and *5* the number of color-fields over frames per second was an even number. If in a trichromatic system all areas of

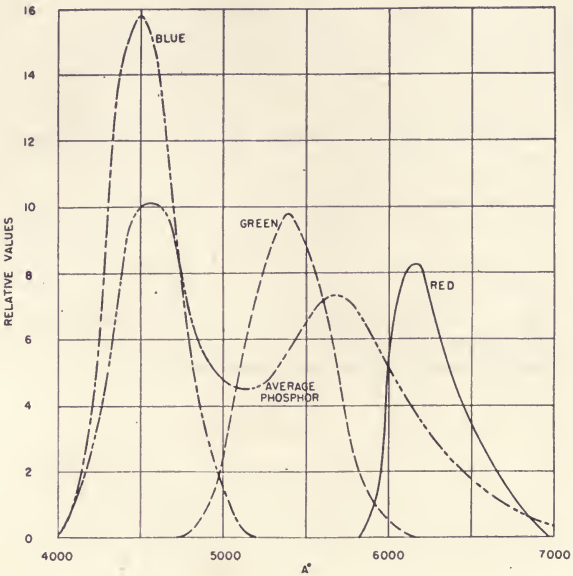

FIG. 3. Color characteristics at the receiver: filters Nos. *47*, *58*, and *26* combined with the phosphor. The fourth curve represents an average phosphor.

the image are to be scanned in all three primary colors, then the following conditions must be fulfilled:

$$\frac{c}{f} = 3n \pm 1$$

where c = color-fields per second
f = frames per second
n = any whole number, 0, 1, 2, 3, *etc.*

For sequential scanning $n = 0$ and thus $c/f = 1$, for $n = 1$, c/f becomes either 2 or 4, which corresponds, respectively, to double and quadruple interlacing. Fig. 1 is a diagrammatic representation of System *3*.

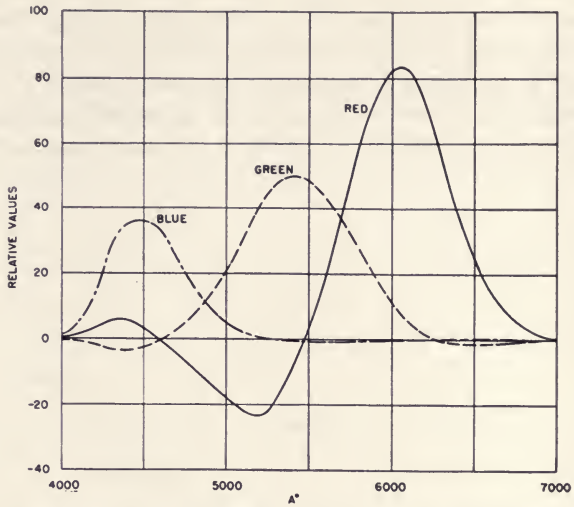

FIG. 4. Color characteristics at the transmitter: these curves are solutions of equation *9* on the basis of receiver characteristics represented in Fig. 3.

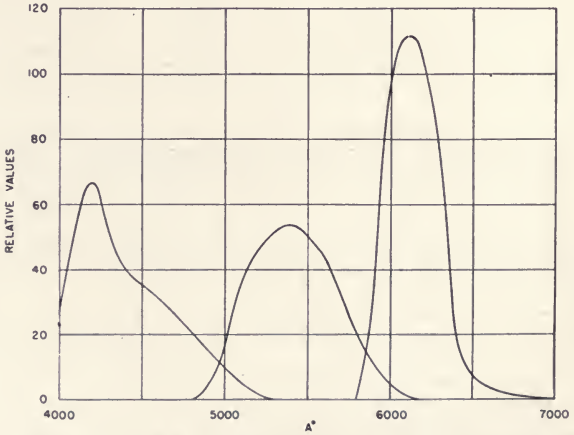

FIG. 5. Color characteristics at the transmitter: the curves combine the standard dissector, the carbon arc, 2 mm of Corning glass No. *978*, and Wratten filters Nos. *25*, *47*, and *58*.

COLOR

The color television method under discussion is based on the eye's retentivity of light of all colors and its ability to recognize mixtures of several colors as a single one. Because of the fact that theoretically all colors are reproducible by a suitable set of three primaries, a trichromatic color system was chosen as the basis for color television.

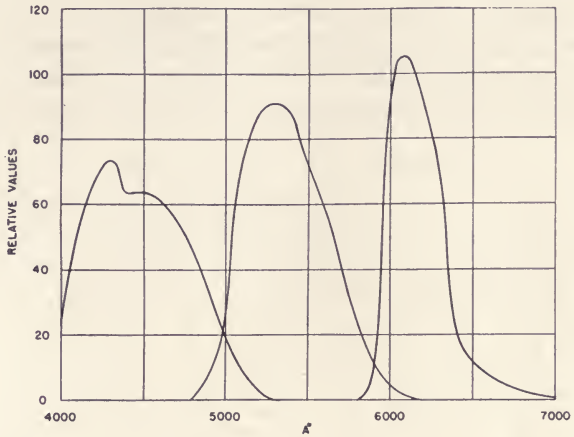

FIG. 6. Color characteristics at the transmitter: the curves combine the daylight dissector attenuated with the carbon arc, 1 mm of Corning glass No. *978*, and Wratten filters Nos. *25*, *47*, and *58*.

The experimental fact that the stimulant $E(\lambda)$ produces a sensation equivalent to a mixture of three primaries can be expressed as:

$$E(\lambda) = w_1(\lambda)I_1 + w_2(\lambda)I_2 + w_3(\lambda)I_3 \qquad (1)$$

where the w's are coefficients and the I's are the three primary colors.

Before proceeding to the discussion of the application of equation *1* and the choice of primaries in reproducing color in television, it is best to introduce some concepts used in standard colorimetry. It can be shown that although the w's can be determined experimentally, there is nothing unique about a given set of primaries and their respective coefficients. The present practice is to use coefficients determined by the International Commission on Illumination in 1931, for the standard observer.[4]

These coefficients, known as the ICI tristimulus values of the spectrum colors, are usually designated by $\bar{x}(\lambda)$ dominant in the red region of the spectrum, $\bar{y}(\lambda)$ in the green, and $\bar{z}(\lambda)$ in the blue region. The tabulated values and the curves for these tristimulus values can be found in several places.[5] The primaries associated with $\bar{x}$, $\bar{y}$, and $\bar{z}$ are fictitious in the sense that they have no physical counterpart. However, they never assume negative values. Purposely $\bar{y}(\lambda)$ was chosen to coincide with the luminosity curve or the standard visibility function and thus represent the energy of the light-source in terms of the eye or the brilliance of the color.

With the aid of the tristimulus values $\bar{x}$, $\bar{y}$, $\bar{z}$, a graphic representation of all colors can be constructed. This is known as the color

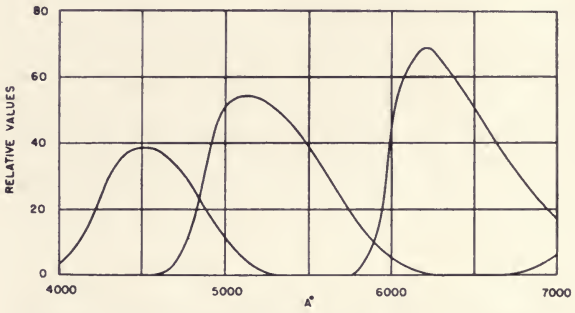

FIG. 7. Color characteristics at the transmitter: Wratten filters Nos. *27*, *47*, and *57* combined with daylight fluorescent light-source as used with orthicons.

triangle, or the unified trichromatic coefficient diagram, and is shown in Fig. 2. The locus of pure spectral colors is shown with a solid curve. This curve is obtained by the so-called unified coefficients, *i. e.:*

$$x = \frac{\bar{x}}{x + \bar{y} + \bar{z}}, \; y = \frac{\bar{y}}{\bar{x} + \bar{y} + \bar{z}}, \; z = \frac{\bar{z}}{\bar{x} + \bar{y} + \bar{z}}; \text{ as a result } x + y + z = 1$$

To determine the tristimulus values for a light-source $E(\lambda)$, an integration must be performed, *i. e.:*

$$X' = \int_0^\infty E(\lambda)x(\lambda)d\lambda, \; Y' = \int_0^\infty E(\lambda)y(\lambda)d\lambda, \; Z' = \int_0^\infty E(\lambda)z(\lambda)d\lambda \quad (2)$$

For these values the unified trichromatic coefficients are:

$$X = \frac{X'}{X' + Y' + Z''}, \; Y = \frac{Y'}{X' + Y' + Z''}, \; Z = \frac{Z'}{X' + Y' + Z'}$$

The light-source $E(\lambda)$ can now be represented by a point in the color triangle. The operation shown in equations *2* can be carried out on luminants of any spectral distribution, such as fluorescent materials, illumination sources with or without color-filters, *etc.*, after which their respective positions in the color triangle can be determined. The second equation in the group determines the luminosity of the color. In Fig. 2, point *w* represents white and greys, *i. e.:*

$$X = Y = Z$$

The gamut of colors which a given set of primaries will reproduce

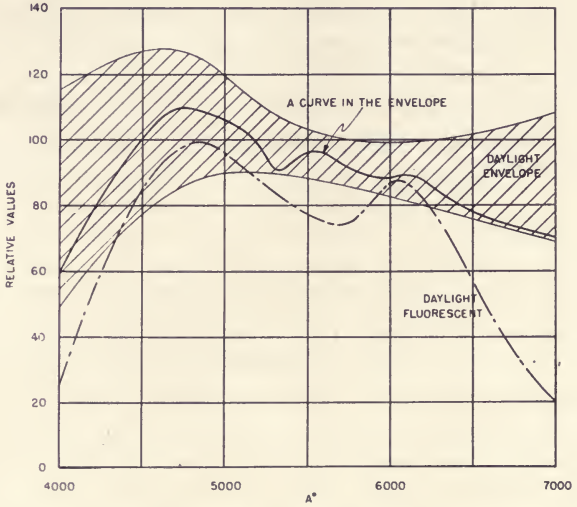

FIG. 8. Comparison of daylight fluorescent light-source with actual daylight.

can be determined with the aid of the color-diagram. (The primaries in this discussion are used only with positive coefficients.) Only those colors enclosed within the triangle, the corners of which are represented by the primaries, can be reproduced by the aforementioned primary colors. Two such triangles are drawn in Fig. 2. In order to reproduce the largest possible gamut, the three primary colors must be so chosen that the resulting triangle encloses most of the colors commonly used. Usually this entails a compromise, with a sacrifice of some of the blue-green region.

The limitations encountered in any two-color system are obvious

when examining Fig. 2. Employing only two primaries, the colors that can be reproduced are only those found along the straight line joining the location of the two primaries in the color triangle.

Color Characteristics at the Receiver.—In the television system under discussion the primaries at the receiver are determined by the color-filters, red, green, and blue, and the fluorescent material in the tube. The largest gamut of colors is produced with primaries which fall on the locus of monochromatic colors in the color triangle. One such choice is red 7000 A, green 5350 A, and blue 4000 A, shown in Fig. 2.

Unfortunately, monochromatic primaries can be obtained only at the sacrifice of light-intensity. Thus one finds that in television, as in certain color-reproducing processes, a compromise must be found between light-intensity and the best choice of primaries. In addition, there is a restricted choice in available phosphors. The decay time of the fluorescent powder used in the receiving tube must be such that its intensity becomes negligible after one color-field period.

Of the commercially available phosphors the zinc and cadmium sulfides possess sufficient luminescent efficiency and also satisfy the decay requirements. The luminescent spectrum of the phosphor must cover the entire range of the three filters in order to provide a light-source for each primary. The precise character of the spectrum desired is contingent upon the choice of filters. The most desirable characteristic would be to furnish maximum light in those blue, green, and red regions that fit the maximum transmission portions of the blue, green, and red filters. Commercial tubes usable for color television employ, for the most part, two component mixtures utilizing a zinc-sulfide with a spectral emission maximum in the blue and blue-green region, and a zinc-cadmium sulfide with a maximum in the yellow and yellow-red region.[7] The spectral curve of such a mixture is shown in Fig. 3.

An inexpensive source of spectroscopically reproducible filters, with a wide color-selection, is the Wratten series, available in gelatin or acetate stock. The choice of the filters is determined by the wavelength at which the maximum transmission occurs, the width of the transmission band, and the total transmission. It is desirable to have filters and phosphor so chosen as to produce white corresponding to 5500°K with equal signals on the grid of the picture tube during the red, blue, and green periods. Thus if a white surface of 5500°K

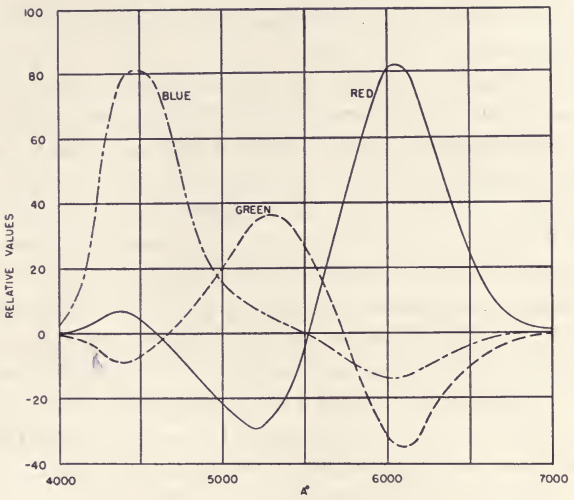

FIG. 9. Solution of equation *9*, including a decay of $^1/_5$ from one color-field to the next in the orthicon.

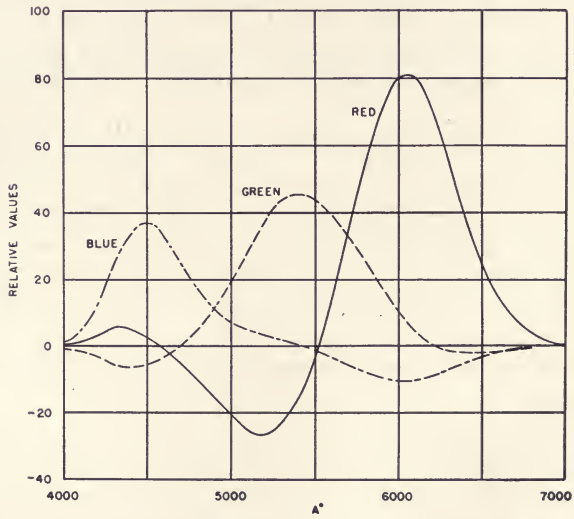

FIG. 10. Solution of equation *9*, including a decay of $^1/_{10}$ from one color-field to the next in the orthicon.

is transmitted, it should be received as the same shade of white and also should be identical to the receiver's own color when operated without a signal.

The filters finally chosen for use at the receiver were Wratten No. *26* for red, No. *47* for blue, and No. *58* for green. The emission curves for the phosphor mixture used for the experimental tubes combined with filters Nos. *47*, *58*, and *26* are given in Fig. 3. The resultant blue, green, and red primaries yield a new color-triangle represented with broken lines in Fig. 2; the location of the new primaries is marked with the corresponding filter numbers.

A satisfactory method of specifying the color composition of the phosphor, which is a mixture of blue, yellow, and orange zinc and zinc-cadmium sulfides, without resorting to actual spectral curve data was to specify the transmission through filters Nos. *47*, *58*, and *26* as recorded with a Weston photocell No. *2*. The relative values which proved satisfactory were No. *47*, 1.0; No. *58*, 1.25; and No. *26*, 0.75. Of the commercially available tubes, the General Electric and Baird have been found quite useful. RCA Radiotron and National Union have supplied special tubes that have proved satisfactory. In the CBS laboratories, tubes have been built using a phosphor mixture containing 60 per cent of a blue zinc-sulfide, 35 per cent of a yellow-green zinc-cadmium sulfide, and 5 per cent of a reddish zinc-cadmium sulfide. The final color characteristic of the tube, however, depends to a large extent upon the various processing schedules.

The range of colors obtainable with this choice of phosphors and filters (shown in Fig. 2 with a dotted triangle) is as large as is encountered in color photography. The white produced with three equal signals appears somewhat bluish. Very recently, however, satisfactory "white" tubes were made in the laboratories, which show consistently good color-characteristics and permit transmitter operation with equal blanking pulses. Spectral curves for these tubes are in preparation and will be available shortly for standardization purposes.

Transmitter Color-Characteristics.—While the performance of the receiver was based upon the theory of color vision, the study of the color-characteristics at the transmitting end of the system had to be guided by the desirability of producing all colors encountered in nature. At the receiver three properly chosen narrow bands in the spectrum were sufficient; at the transmitter, the bands must be wide

enough and sufficiently overlapping to produce a signal from every color. The exact character of the three spectral curves at the transmitter is determined by the filter and phosphor combination at the receiver.

The spectral characteristics at the transmitter are composed of the spectral sensitivity of the pick-up tube in the camera, the transmission curves of the filters, and the spectral emission of the light-source. The filters and light-source must be so chosen as to produce negligible signals in the infrared (beyond 7000 A) and the near ultra-violet (below 4000 A) regions of the spectrum.

The general relationship between the color-characteristics of the transmitter and the receiver can be derived from an analysis developed by Hardy and Wurzburg in connection with photographic reproduction in color.[6]

The tristimulus values for any object at the transmitter, the spectral reflection of which is represented by $E(\lambda)$, was given by equation *2*. At the receiver the tristimulus values are represented by:

$$\begin{aligned} X'' &= r\int_0^\infty P(\lambda)F_r(\lambda)\bar{x}(\lambda)d\lambda + g\int_0^\infty P(\lambda)F_g(\lambda)\bar{x}(\lambda)d\lambda + b\int_0^\infty P(\lambda)F_b(\lambda)\bar{x}(\lambda)d\lambda \\ Y'' &= r\int_0^\infty P(\lambda)F_r(\lambda)\bar{y}(\lambda)d\lambda + g\int_0^\infty P(\lambda)F_g(\lambda)\bar{y}(\lambda)d\lambda + b\int_0^\infty P(\lambda)F_b(\lambda)\bar{y}(\lambda)d\lambda \\ Z'' &= r\int_0^\infty P(\lambda)F_r(\lambda)\bar{z}(\lambda)d\lambda + g\int_0^\infty P(\lambda)F_g(\lambda)\bar{z}(\lambda)d\lambda + b\int_0^\infty P(\lambda)F_b(\lambda)\bar{z}(\lambda)d\lambda \end{aligned} \tag{3}$$

The coefficients r, g, and b are proportional to the light-intensities at the picture tube associated with signals generated at the camera through the red, green, and blue filters. $P(\lambda)$ is the spectral emission of the phosphor. $F_r(\lambda)$, $F_g(\lambda)$, and $F_b(\lambda)$ are the spectral transmissions of the red, green, and blue filters at the receiver, and $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, and $\bar{z}(\lambda)$ are the ICI tristimulus values.

The r, g, and b are some functions of the light incident at the photosensitive member of the camera tube, *i. e.:*

$$r = f(S_r),\ g = f(S_g),\ b = f(S_b) \tag{4}$$

Simplified for further discussion, equation *3* can be written as:

$$\begin{aligned} X'' &= ra_{11} + ga_{12} + ba_{13} \\ Y'' &= ra_{21} + ga_{22} + ba_{23} \\ Z'' &= ra_{31} + ga_{32} + ba_{33} \end{aligned} \tag{5}$$

For the system to reproduce color faithfully it is necessary that equations *2* and *3* be related linearly, *i. e.:*

$$X' = kX'';\ Y' = kY'';\ Z' = kY^k \tag{6}$$

where k is a constant.

The S_r, S_g, S_b of equation *4* is that portion of the light at the transmitter which is useful in producing the electrical signal. It can be resolved into three components: $A(\lambda)$, the spectral sensitivity of the photosensitive member of the camera tube, the spectral attenuation of the red, green, and blue filters at the camera tube, $T_r(\lambda)$, $T_g(\lambda)$, and $T_b(\lambda)$ and the spectral distribution of the object $E(\lambda)$ being televised. $E(\lambda)$ will depend upon the light-source used to illuminate the object. The S's can thus be written as:

$$\begin{aligned} S_r &= \int_0^\infty E(\lambda)T_r(\lambda)A\lambda \,.\, d\lambda \\ S_g &= \int_0^\infty E(\lambda)T_g(\lambda)A\lambda \,.\, d\lambda \\ S_b &= \int_0^\infty E(\lambda)T_b(\lambda)A\lambda \,.\, d\lambda \end{aligned} \tag{7}$$

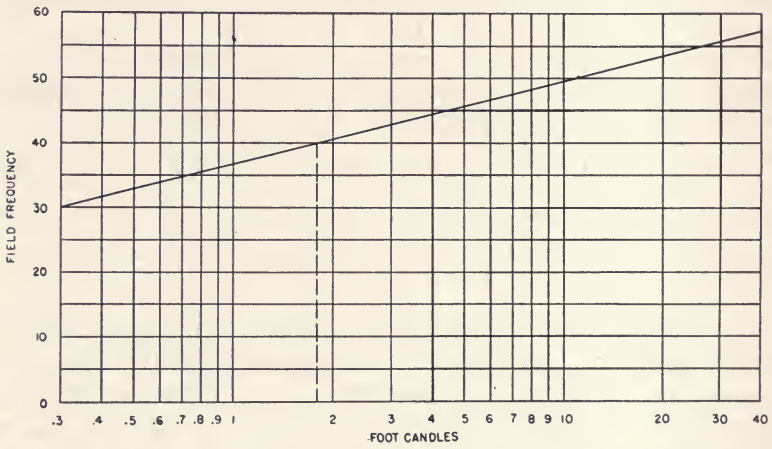

FIG. 11. Relationship between critical flicker frequency and picture brilliance.

The actual functional relation between r and S_r, *etc.*, depends upon the relationship between the light input and the signal output at the camera, on the relationship between the voltage on the grid of the receiving picture, and the light output from the phosphor; it further depends upon the electrical characteristics of the terminal equipment, the transmitter proper, and the receiver.

Equations *2* and *3* permit the determination of

$$T_r(\lambda)A(\lambda),\ T_g(\lambda)A(\lambda), \text{ and } T_b(\lambda)A(\lambda)$$

for a given light-source. Once $P(\lambda)F_r(\lambda)$, $P(\lambda)F_g(\lambda)$, and $P(\lambda)F_r(\lambda)$ have been chosen and provided it is assumed that $r = S_r$, $g = S_g$,

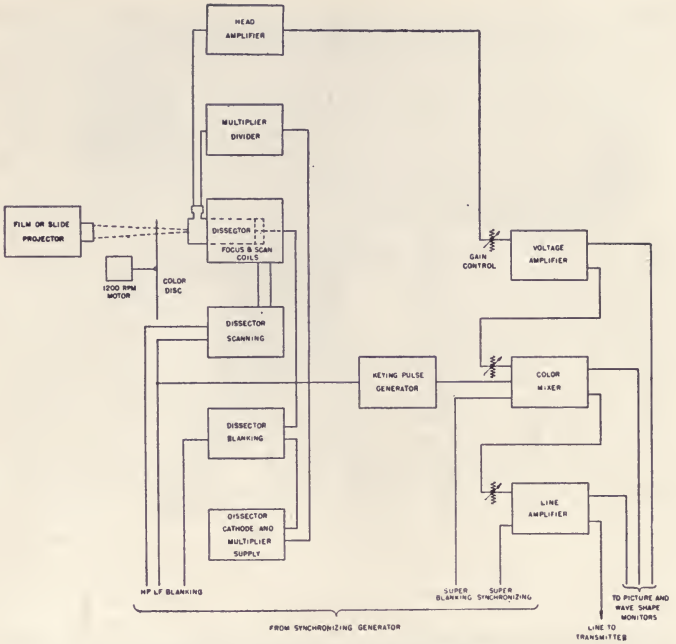

FIG. 12. Dissector block diagram.

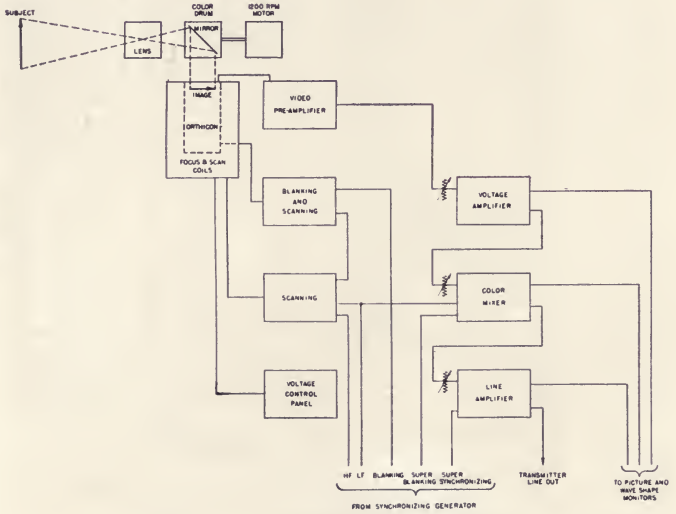

FIG. 13. Orthicon block diagram.

FIG. 14. Orthicon camera on tripod; direct pick-up color-camera.

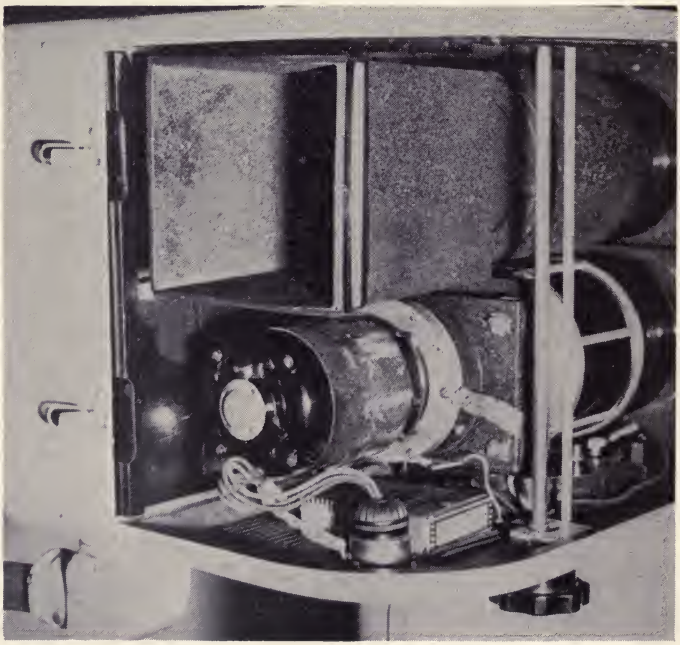

FIG. 15. Orthicon color-camera; inside view, showing filter-drum with synchronous driving motor.

and $b = S_b$. This in effect signifies that the gamma of the overall system is unity. If equation *5* is substituted in *2* the new equation is in turn substituted with equation *7* into *3*, and the integral sign and $E(\lambda)$ are cancelled heuristically from both sides, the resulting relationship is:

$$\begin{aligned}\bar{x}(\lambda) &= T_r(\lambda)A(\lambda)a_{11} + T_g(\lambda)A(\lambda)a_{12} + T_b(\lambda)A(\lambda)a_{13}\\ \bar{y}(\lambda) &= T_r(\lambda)A(\lambda)a_{21} + T_g(\lambda)A(\lambda)a_{22} + T_b(\lambda)A(\lambda)a_{23}\\ \bar{z}(\lambda) &= T_r(\lambda)A(\lambda)a_{31} + T_g(\lambda)A(\lambda)a_{32} + T_b(\lambda)A(\lambda)a_{33}\end{aligned} \qquad (8)$$

The color-response at the transmitter is contained in the quantities $T_r(\lambda)A(\lambda)$, $T_g(\lambda)A(\lambda)$, and $T_b(\lambda)A(\lambda)$. In equation *8* the coefficients a_{mn} are known constants that are evaluated in terms of color-response at the receiver and the ICI tristimulus values. Equation *8* can thus be written as:

$$\begin{aligned}cT_r(\lambda)A(\lambda) &= (a_{22}a_{33} - a_{23}a_{32})\bar{x}(\lambda) + (a_{13}a_{32} - a_{12}a_{33})\bar{y}(\lambda) + (a_{12}a_{23} - a_{22}a_{13})\bar{z}(\lambda)\\ cT_g(\lambda)A(\lambda) &= (a_{23}a_{31} - a_{21}a_{33})\bar{x}(\lambda) + (a_{11}a_{33} - a_{13}a_{31})\bar{y}(\lambda) + (a_{13}a_{21} - a_{11}a_{23})\bar{z}(\lambda)\\ cT_b(\lambda)A(\lambda) &= (a_{21}a_{32} - a_{22}a_{31})\bar{x}(\lambda) + (a_{12}a_{31} - a_{11}a_{32})\bar{y}(\lambda) + (a_{11}a_{22} - a_{12}a_{21})\bar{z}(\lambda)\end{aligned} \qquad (9)$$

where c is a constant. The solution of *9* in terms of receiver color-response as represented in Fig. 3 is shown in Fig. 4. The curves in these figures display the usual characteristics found in all color-reproduction problems—the existence of negative color values for perfect matching. The present color television system has no mechanism to introduce these negative values; however, they are being partially compensated for with the aid of the color mixer.

The above analysis is valid for the color-transmission of live scenes as well as for color-slides or motion pictures, provided the latter two contain no color distortion. Once the photographic or printing processes have introduced certain distortions, the filters at the transmitter must be so chosen as to compensate, if possible, for these specific anomalies.

Camera Tubes.—Before comparing the results contained in Fig. 4 with actual operating conditions it is best to consider briefly the color-characteristics of the tube used at the transmitting end. They are of two types: the dissector, used for slides and motion pictures, and the orthicon, used in the studio and in outdoor pick-ups. One of the problems in dissector operation is the elimination of signals produced with infrared radiation. The infrared contaminates all colors as it passes freely through the red, blue, and green filters. Originally the standard dissector was used with a cesiated silver oxide cathode surface. This surface has a minimum color-response in the

green portion of the spectrum while it shows rising tendencies toward both the blue and the infrared regions. In order to utilize this tube a carbon arc was used as a light-source, combined with the infrared-absorbing Corning glass filter No. *978*, 2 mm thick. The filters that were used in this set-up were Wratten Nos. *47*, *58*, and *25*. Fig. 5 is a graphic representation of the results. The dissector used at present is the so-called daylight dissector (developed especially for color television by the Fransworth Television and Radio Corporation) with a maximum in the green portion of the spectrum falling off toward the blue and the red end. This dissector was used also with

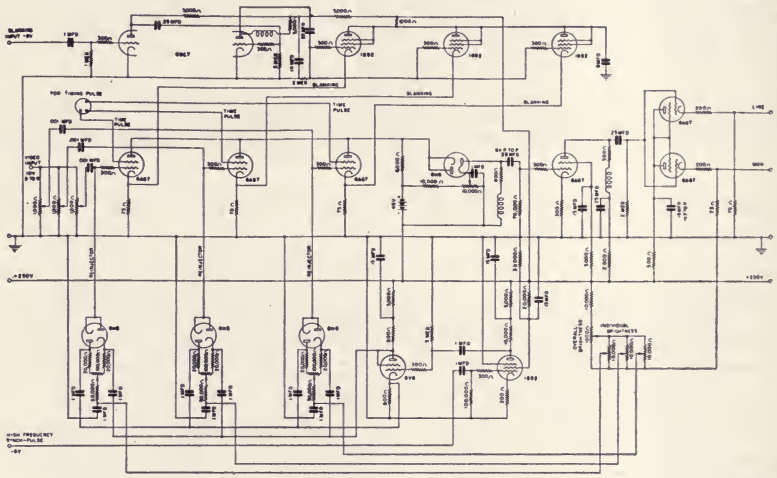

FIG. 16. Color-mixer amplifier.

a carbon arc but with a Corning filter No. *978* only 1 mm thick. The color-filters were again Nos. *47*, *58*, and *25*. In both cases a water-cell was used to protect the slides and film. Fig. 6 gives the operating conditions for the daylight dissector. There is no question of the superiority of this type of tube over the standard dissector for this work. The signal-to-noise ratio is improved partly because of the greater photoelectric response in the pertinent portion of the spectrum and also because of the reduction in thickness of the infrared filter.

The spectral characteristics of the orthicon have not been measured under operating conditions. However, from measurements of the signal obtained through various Wratten filters it can be stated

very generally that the spectral response of the color orthicon does not conform to the standard cesiated silver oxide surface. It was found that specifications of the color characteristics of the orthicons used can be summed up in terms of the signal obtained through Wratten filters Nos. *47*, *57*, and *25*. The ratio of the signals through Nos. *47* to *57* using a daylight fluorescent light-source is approximately 1.25, and the ratio of No. *47* to No. *25* is 0.85. To obtain a general view of the color characteristics at the transmitter a daylight fluorescent light-source attenuated through filters Nos. *47*, *57*, and *25* has been plotted in Fig. 7. The inclusion of the characteristics of the orthicon in this figure will reduce the red curve roughly by 30

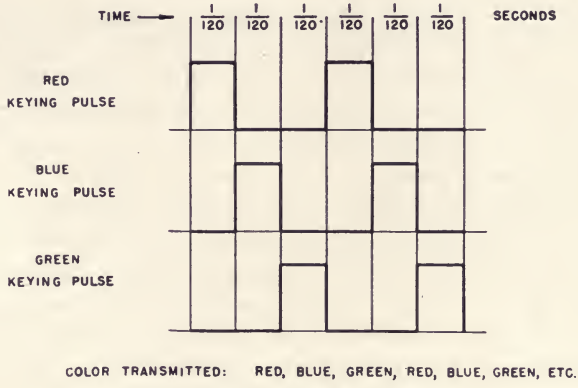

FIG. 17. Color-mixer pulse diagram.

per cent. It may shift the maxima slightly but will not change the limits of the individual curves. Thus the extent of filter overlapping remains the same.

Lighting.—The color-characteristics at the transmitting end of the system depend to a large extent upon the illumination source. For slides and motion pictures the carbon arc is used and the filters are chosen to match the carbon arc. For direct pick-up it is desirable to have a light-source such as not to necessitate the change of filters when the camera is moved outdoors. A good approximation to such a light-source can be obtained with incandescent lamps where the infrared is attenuated with properly chosen glass filters, such as Aklo glass. However, this type of source is very inefficient. Fluorescent lamps of the daylight type are a fair approximation to the requirements. The lamps contain 30-watt bulbs mounted in spe-

cially designed reflectors, developed for color television to give the maximum light-flux for a minimum ceiling area. A single unit is shown in Fig. 31 and a bank in Fig. 32.

Fig. 8 gives the spectral emission curve for the daylight fluorescent lamps. The spectral distribution of light as received from the sun on a horizontal plane under various cloud conditions and at different times of day also is shown.[8]

It can be seen that the daylight fluorescent lamps are down in the red and slightly down in the blue portions of the spectrum as compared to outdoor illumination. It was found that when switching from studio pick-up to outdoor scenes it is necessary to reduce the red signal by means of the electrical color mixer.

Comparison of Figures.—The calculations culminating in Fig. 4 have been purposely kept in general terms using a light-source of uniform energy-distribution over the visible spectrum. Figs. 5 through 7 take into consideration the actual light-source in order to show the signal magnitude through the filters and the attenuation of the infrared component.

It follows that the comparison of Fig. 4 with Figs. 5 to 7 must be very general. The spectral characteristics of operational equipment lack the negative value. The maxima are roughly in the same region, and the limits of the blue and green curves, which are principally determined by the Wratten filters, correspond quite closely. A certain discrepancy exists in the reds, where in Fig. 4 the cut-off is at 5500 A and in Fig. 7 at 5800 A. When examining Fig. 5 carefully, one can see that monochromatic sources between 4000–4800 A will appear as the same blue, those between 5400–5800 A will appear as the same green, and those between 6300–6700 A will appear as the same red at the receiver. However, these imperfections are not too serious, since only rarely do objects reflect colors of such narrow bands.

As has been pointed out previously, this color television system does not permit introducing the negative values (which are common to most color-reproducing systems) as shown in Fig. 4. Nevertheless, the color-mixer permits partial compensation by changing the ratio between signals r, g, and b. The system itself in unaware of whether the change takes place in the spectral characteristics of the light-source at the transmitting end or in light-emission of the receiver. Changing the relative amounts of the red, blue, and green signals electrically in effect changes the solution of equation *9*. Thus the

manipulation of the color-mixer changes the ratio of positive to negative signal. Color deterioration resulting from the lack of negative signal is thus partially reduced.

In this analysis, the persistence of a signal from one color-field to the following ones, as experienced in the orthicon under certain contions, has been neglected. Curves similar to those in Fig. 4 have been calculated, taking into account hangover of 1 : 5 and 1 : 10 of the original signal into the next field for a color-sequence red-blue-green, and are shown in Figs. 9 and 10. The same receiver

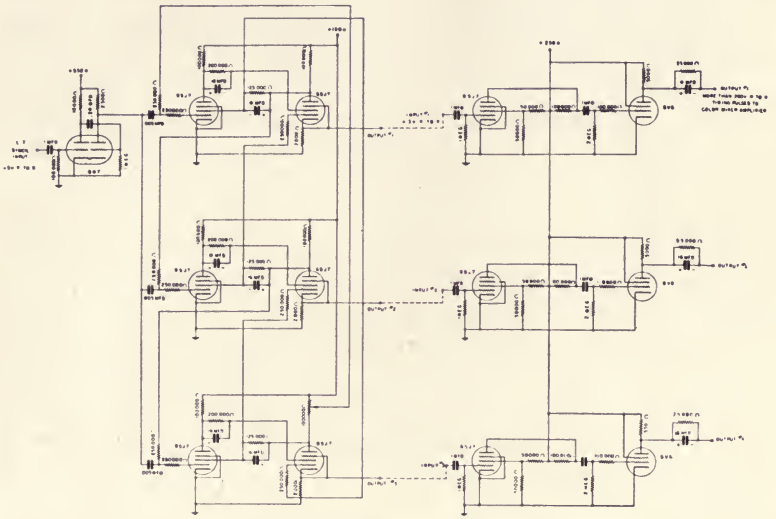

FIG. 18. Color-mixer pulse generator.

color-characteristics as in Fig. 4 were assumed. The most outstanding feature of these curves is the increased amplitude and width of the negative portions. A hangover of 1 : 5 (Fig. 9) would require much broader filters at the transmitter and the color contamination would be appreciable. A hangover of 1 : 10 (Fig. 10) shows less deviation, as compared with conditions in Fig. 4, where no hangover was assumed. The blue filter is wider than in Fig. 4 and has a negative component in the red region. On the whole, however, Fig. 10 matches Fig. 4 reasonably well.

The color-mixer has been used to compensate for different lighting conditions to correct for color contamination resulting from lack of negative signal, and thus also indirectly for hangover. There is no

assurance that all these corrections require the same adjustment. The mixer permits a partial removal of color contamination from a number of sources and in actual operations a compromise is made for the best overall effect.

The analysis has been based on a linear relationship between light output at the receiver, *i. e.*, a system with unity gamma, which conditions may not be obtained with present equipment.

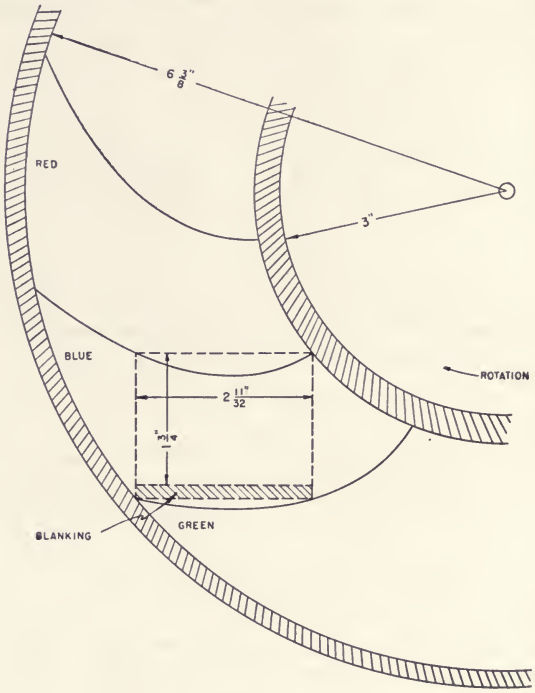

FIG. 19. Filter disk for orthicon.

FLICKER IN COLOR TELEVISION

The well known Ferry-Porter[9] law states that the critical frequency is proportional to the logarithm of the illumination intensity. Porter was the first to establish the fact that the critical fusion frequency is independent of wavelength, provided the apparent brilliance remains constant. Based on this law he derived the well known color-intensity curve of the eye using a flicker photometer. It follows

that with constant illumination over the visual spectrum the eye's sensitivity to flicker follows the color-intensity curve.

In the sequential color television system under consideration the worst flicker condition would occur if only the primary color with the highest luminosity were received while the other two primary colors were suppressed completely. Such a condition hardly ever occurs in practice unless the color camera picks up a green object, the limits of its chromaticity being between 5400 A and 5800 A (see Fig. 5). The flicker frequency for this case would be 40 per second. An attempt will be made to calculate the maximum permissible brilliance of such a green picture before flicker becomes perceptible.

The validity of Talbot's law has been checked for all colors by Porter[10] and others. Thus, applying Talbot's law to the special case of color television as discussed here, the apparent brilliance of the image at the receiver would be:

$$I_A = \frac{1}{T_c}\int_0^T L(t)dt \qquad (10)$$

where T_c is the duration of a complete color-cycle (color-frame) and T the duration of a color-field. $L(t)$ is the decay function of the screen material. This is assumed to be exponential, with a luminosity not greater than one-tenth of the initial brilliance after the duration of one field period T.

Thus for the transmission of green between 5400 A and 5800 A the apparent brilliance of the received picture becomes:

$$I_g = \frac{Y_g}{T_c}\int_0^T L(t)dt \qquad (11)$$

where the luminosity at the receiver $L(t)$ is multiplied by the Y component of the unified trichromatic coefficients, representing the combination of the receiver's green filter and the screen material, as shown in the color diagram Fig. 2.

For a picture tube made in the laboratories especially for color reception the following ratios of the luminosity values of the three color primaries were found:

$$\frac{Y_{\text{green}}}{Y_{\text{blue}}} = 23 \text{ and } \frac{Y_{\text{red}}}{Y_{\text{blue}}} = 10.5 \qquad (12)$$

Substituting in formula *11* for $T_c = {}^1/_{40}$ and for $T = {}^1/_{120}$ second and solving the integral, we obtain for the apparent brilliance which is furnished during the green period only:

$$I_g = \frac{23 Y_b}{40}\int_0 L(t)dt \qquad (13)$$

In order to determine at what apparent brilliance a 40-cycle television picture will just begin to show flicker we consult the curve shown in Fig. 11, which is from the article entitled "Television Image Characteristics" by Engstrom.[10] The curves were obtained by using a special film which corresponded to certain decay characteristics of screen materials. It was decided to choose film No. *1*, the decay characteristic of which is sufficiently fast to correspond to a screen material usable in color television where at the end of one frame the screen brilliance decays practically to zero. Thus, according to Fig. 11, a repetition frequency of 40 per second will permit a screen illumination of 1.8 apparent foot-candles.

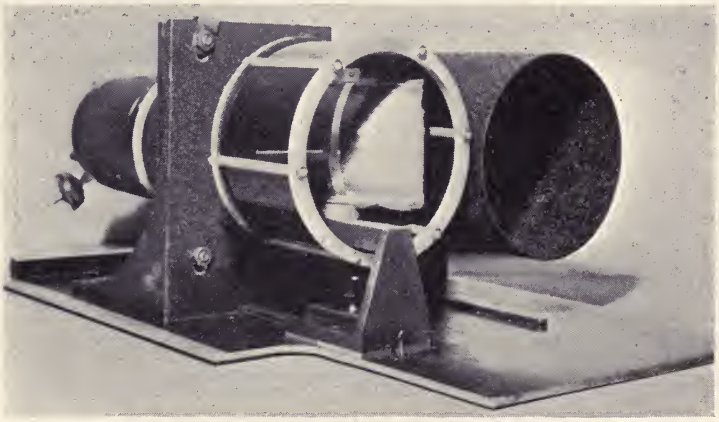

FIG. 20. Orthicon color-camera; filter-drum assembly.

So far we have considered the most unfavorable case from a flicker point of view. More favorable conditions will occur if white with three equal electrical impulses during the red, green, and blue periods is transmitted and received.

In order to obtain the total apparent illumination at the receiver, formula *11* will be expanded into:

$$I_w = \frac{1}{40}\left(Y_r + Y_g + Y_b\right)\int_0^T L(t)dt \qquad (14)$$

It has been assumed that the spectral characteristic of the phosphor does not change during the decay.

Substituting for $Y_g = 23Y_b$ and $Y_r = 10.5Y_b$ from equation *14* we obtain:

$$I_w = \frac{34.5}{40} Y_b \int_0^T L(t)dt \qquad (15)$$

previously (*13*) it was found that

$$I_g = \frac{23}{40} Y_b \int_0^T L(t)dt$$

and thus

$$\frac{I_w}{I_g} = \frac{34.5}{23} \qquad (17)$$

FIG. 21. Nine-inch color television receiver; front view.

The meaning of this expression is that the apparent brilliance of the receiver screen increases only in the ratio of 34.5/23 when white is transmitted, even though it is produced by three equal electrical impulses, one during each color-field. Since in this case a light-impulse is received during each of the color-fields, flicker conditions improve rapidly. However, the apparent brilliance should not be higher than 1.8 times 34.5/23 which is 2.7 apparent foot-candles, if one wishes to make sure that in the singular case of the transmission of a narrow band of green no flicker is present. This top value of 2.7 foot-candles is not a serious limitation. Present black-and-

white pictures with such a highlight brilliance give satisfactory viewing in darkness. The same black-and-white receiver, however, will not permit satisfactory viewing with surrounding illumination of any appreciable magnitude.

Color television pictures produced with the aid of rotating filters do not deteriorate appreciably in surrounding illumination due to the fact that the room light which passes through the filters twice is attenuated by the square of the filter-loss factor, while the picture itself is attenuated only by the first power of the filter-factors.* As

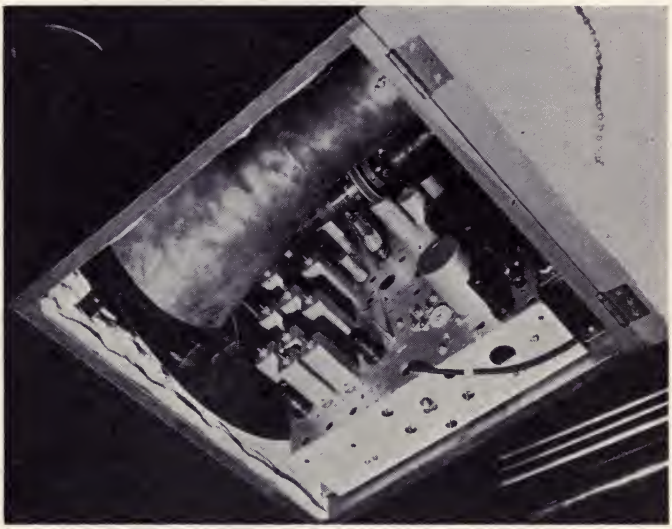

FIG. 22. Nine-inch color television receiver; top view, open.

a result the unmodulated screen of a color receiver appears nearly black even in a well illuminated room. Thus the 2.7-foot-candle maximum brilliance will furnish a more satisfactory image than a conventional black-and-white receiver even with 10-foot-candle highlight illumination.

EQUIPMENT FOR COLOR TELEVISION

Studio.—Certain electrical requirements must be met by pick-up tubes if they are to be used in color television. It is important that

* A black-and-white receiver with an equivalent neutral filter will resist room illumination to the same extent.

the signals produced during any one color-field should not be adulterated by a signal left over from a previous field. Storage-type camera tubes must, therefore, be designed so that the entire electrical charge on the mosaic is removed within one field period.

A constant black level must be established in the camera tube, and spurious signals such as "shading" should be absent. The dissector is the only commercial camera tube that meets all the above requirements, though its usefulness is limited to the transmission of film or slides due to its low sensitivity.

The orthicon as modified for color television with lower mosaic capacity was developed through the coöperation of the RCA Radio-

FIG. 23. Seven-inch color television receiver; front view.

tron Division and has been found to produce very acceptable color-pictures with incident light of 150 foot-candles on the subject. A certain amount of "hangover," which may be defined as the amount of signal remaining on the mosaic after the scanning beam has completed one field, appears to be unavoidable, but is troublesome only at lower light levels. The hangover occurs when the potentials on the mosaic are small enough to be within range of the random velocity distribution of the scanning beam. Under this condition the charge is not completely removed until the mosaic has been scanned several times. A lower mosaic capacity permits the voltage on the mosaic (for a given illumination) to build up to higher levels.

It might be expected that difficulty would be experienced with

interlaced scanning on a storage-type camera tube such as the orthicon. In an ideal storage tube, where the scanning spot is only one line wide, it will be apparent that at the end of one field-scanning period only one-half the lines will be scanned and the hangover will be 100 per cent. Actually, in practice, hangover ratios of from 1 : 5 to 1 : 1 are obtained with the orthicon, indicating that either leakage, defocusing, or other effects are present to such an extent as to remove most of the unscanned picture at the end of one field scansion.

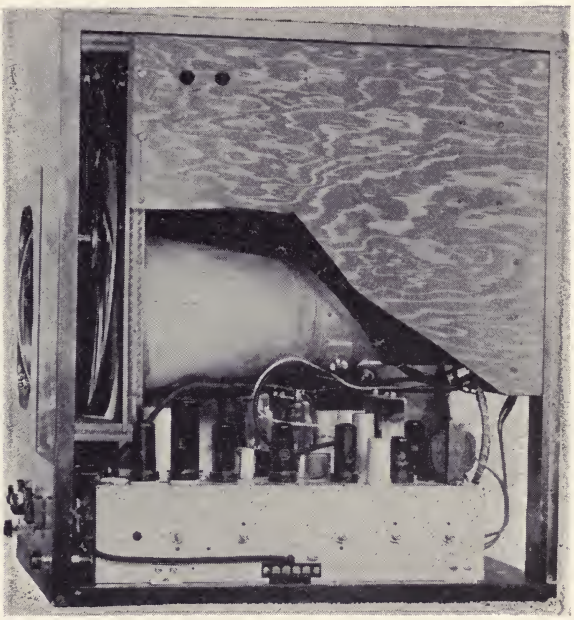

FIG. 24. Seven-inch color television receiver; top view, open.

The gamma of a camera tube need not necessarily be unity, as correction may be made for any particular characteristic later on, if desired. In general, a television system employing a linear pick-up tube, such as an orthicon, will have an overall gamma higher than unity, due to the cathode-ray tube. A reduction in the gamma may be more satisfactorily made with tubes of the dissector type, where the noise is negligible in the black portions of the picture, than in a tube of the orthicon type, where the noise is determined by the impedance of the tube and the first amplifier stage. A reduction of

gamma in the latter case results in increased noise in the blacks, if all other factors remain equal.

The introduction of color does not change many of the design requirements which are ordinarily encountered in monochromatic tele-

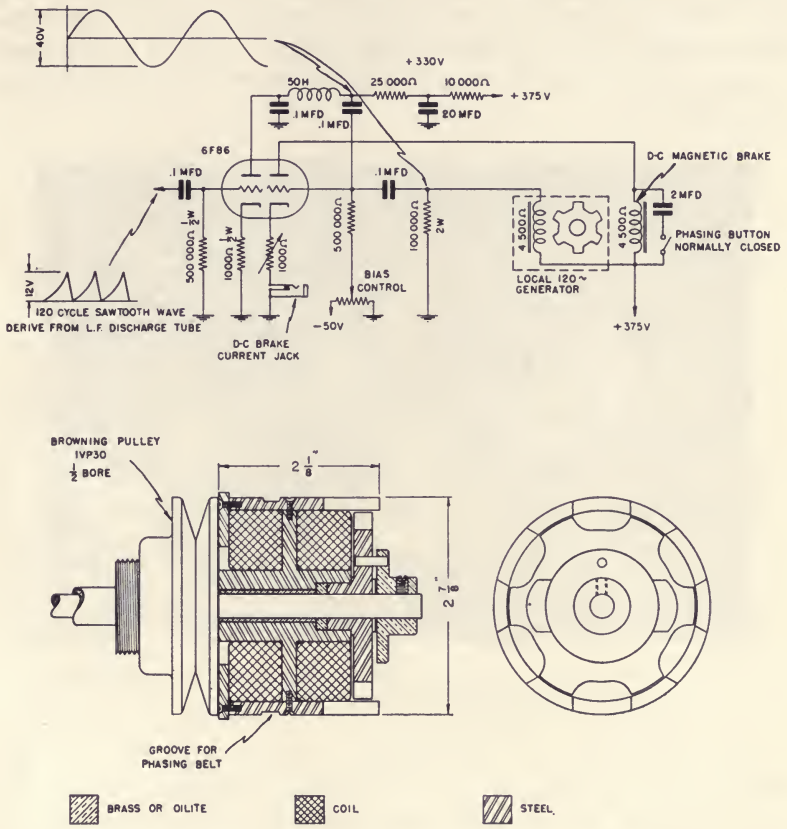

FIG. 25. Seven-inch receiver brake circuits and design.

vision studio equipment. Certain factors, however, are worthy of mention. The color-field frequency of 120 per second necessitates freedom from 60-cycle hum in the synchronizing generator and scanning equipment and, to a lesser degree, in video amplifiers. Sixty-cycle components present in the synchronizing generator or scanning equipment cause loss of interlace and in the video equipment cause flicker at a 20-cycle rate resulting from the beat between the 60-

cycle hum and the 40-cycle picture components. Hum may be eliminated easily by operating the equipment on a 120-cycle power-source.

Good low-frequency response is necessary in video amplifiers to pass the 40-cycle picture components properly. The video control equipment for color is somewhat more complex than for black-and-white transmission, as it seems advantageous to control the gain and possibly the background of each color independently, as previously mentioned.

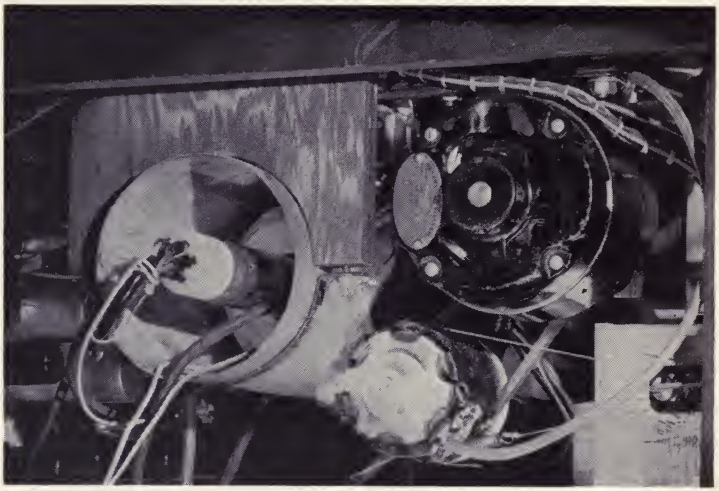

FIG. 26. Seven-inch color television receiver, showing synchronizing brake and driving-motor assemblies.

Block diagrams of a color television system using dissector and orthicon camera tubes are shown in Figs. 12 and 13. Photographs of the orthicon direct pick-up color-camera are shown in Figs. 14 and 15. As previously mentioned, it is essential that the black level be established at the camera since manual control of the d-c level for each color would seem a tremendous task. This is done by applying the blanking pulses to the grid of the orthicon and to the cathode of the dissector.

The video amplifiers in a color television camera channel are conventional except for the color-mixer. Manual control of gain and brightness for each color are achieved by the equipment shown in Fig. 16. The color-mixer amplifier may be described as an elec-

tronic switch combined with three separate amplifiers, each with its own gain and brightness controls. The video signal is switched by means of suitable timing pulses (Fig. 17) applied to the screen grids of the *6A67* switching amplifier tubes. The pulses are so timed as to operate each amplifier in succession, turning on one as another is

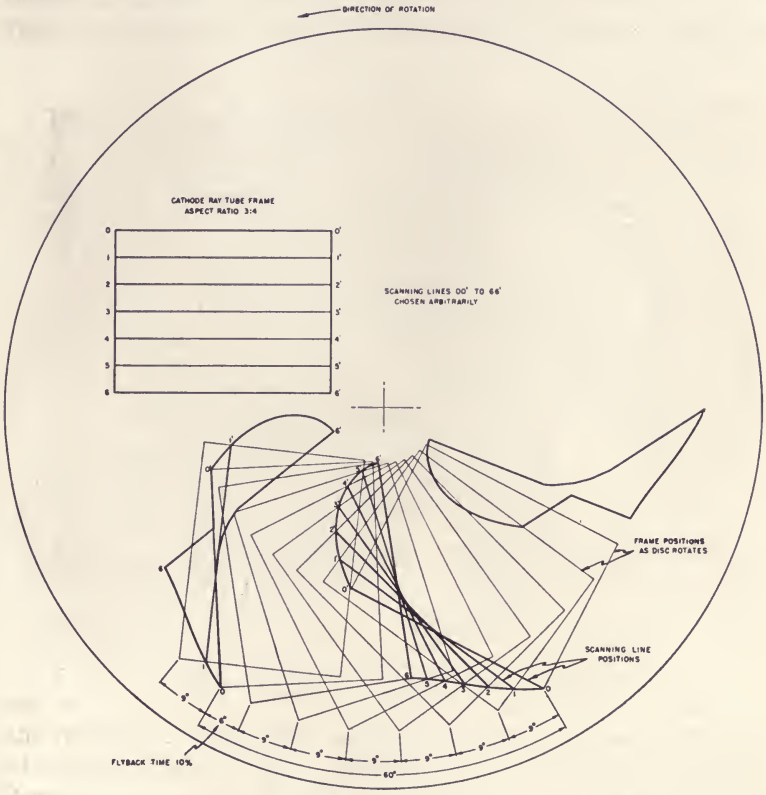

FIG. 27. Generation of filter shapes

turned off. This switching occurs during the blanking period, and switching transients are removed by subsequent clipping of the recombined signals. Blanking is injected on the cathode of each switching amplifier tube and the individual brightness of each color is adjustable by bias controls. The switching pulses are generated by the "ring-frequency divider" circuit shown in Fig. 18.

The non-storage dissector is more easily adapted to a filter disk, since it is necessary that the optical image on the cathode be of the correct color only at the point which is being scanned. The orthicon, on the other hand, being of the storage type, requires that only one color be present in the optical image for one complete scanning-field period, prior to the actual scansion of a given point. It is possible to design a disk to fulfill this requirement, but it will be of considerably larger diameter than the filter disk for the dissector. Fig. 19

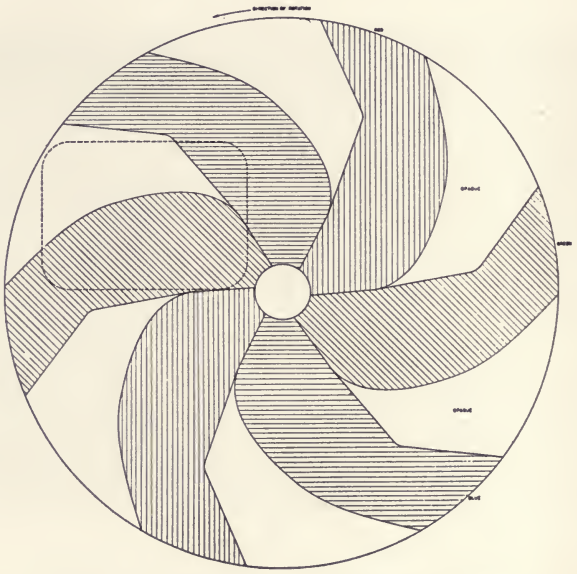

FIG. 28. Typical receiver filter disk design.

shows the filter disk for the orthicon, where the contamination of colors due to the curvature of the filter segments is not more than 10 per cent. A filter-drum as shown in Fig. 20 accomplishes the same purpose with less contamination and less space. The drum is phased so that the shadow of the slotted rods holding the filters follows the scanning line.

Receiving Equipment.—Practically any good black-and-white television receiver design may be the basis of a color television receiver. Typical color receivers are shown in Figs. 21, 22, 23 and 24. The additional equipment required will be the color disk, with its driving and synchronizing means.

Usually additional precautions should be taken to insure complete d-c component insertion and freedom from hum. The cathode-ray tube should be magnetically shielded to minimize pairing due to 60-cycle hum. It is fully as important, however, that attention be paid to sources of hum in the scanning circuit, such as common ground returns carrying alternating current, insufficient power-supply

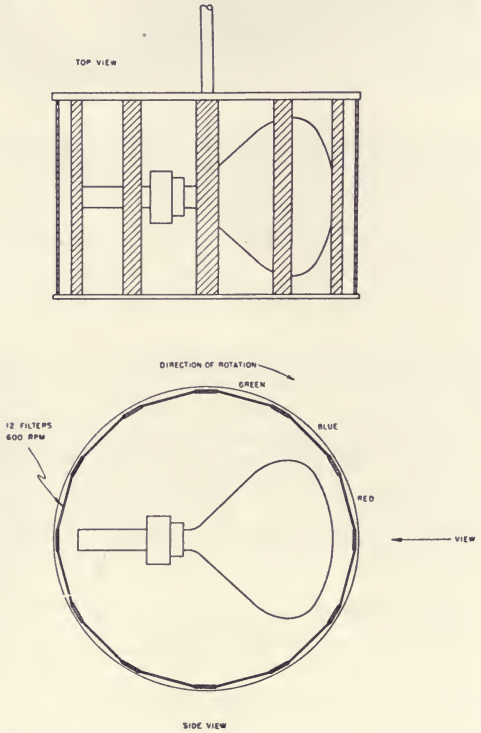

FIG. 29. Drum receiver.

filtering, or magnetic coupling from power equipment into scanning transformers. It has sometimes been found economical to inject hum in opposing phase to neutralize a-c fields that otherwise may be difficult to remove. This is possible only when the interfering hum remains constant in phase and amplitude with respect to the neutralizing components. Another effect which sometimes tends to destroy interlacing is found in the electrostatic charges which accumulate on the rapidly moving color disk. Variations in the charge

over the surface of the disk produce movement of the scanning lines as the disk rotates. It is possible to remove the charge with a semi-

FIG. 30. Rectangular flat-screen cathode-ray tube for color television.

conductive coating on the cathode-ray tube face or with other electrostatic means of screening.

Color disks have been made of metal or of transparent plastics

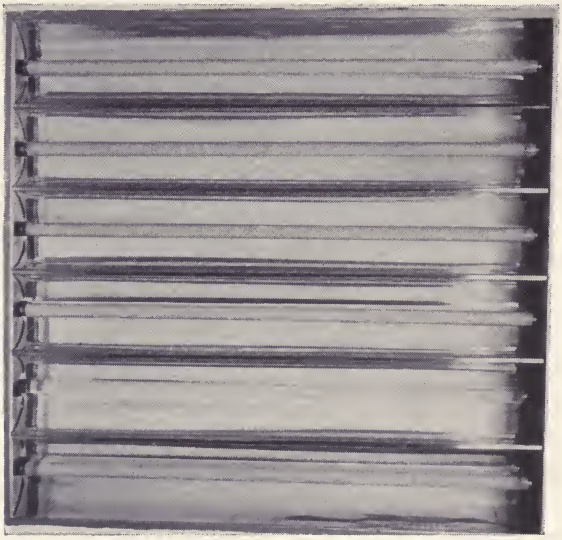

FIG. 31. A fluorescent-light unit, used in color work.

such as Lucite, Plexiglass, *etc.* Wratten filters may be obtained coated on a 0.010-inch acetate stock which can be riveted to the plastic or metal disk. The disk may be rotated by a synchronous

motor or by an asynchronous motor with auxiliary synchronizing means. Owing to lack of synchronism between the power supplies of New York, Connecticut, and New Jersey, and also owing to lack of standard synchronous motors of 1200-rpm type, it was found desirable to drive the disk with inexpensive induction-type motors and synchronize it by means of a phonic motor or a magnetic brake. Satisfactory phonic motors have been constructed driven by a single *6V6* tube, but the brake arrangement is preferred (Fig. 25). A photograph of the same brake assembly as used on the receiver of Fig. 23 is shown in Fig. 26. The 120-cycle voltage is derived from

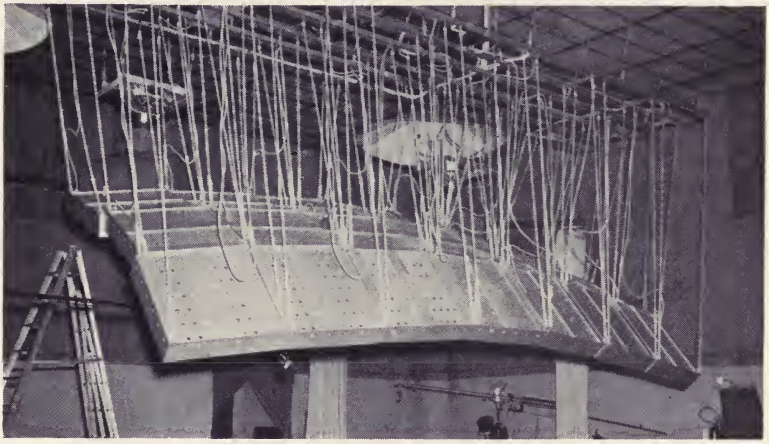

FIG. 32. View of a bank of fluorescent lights.

the low-frequency scanning circuit and is mixed with a similar voltage from a small generator on the disk shaft. The sum of the voltages is then rectified and the resulting direct current applied to the magnetic brake. A departure in the disk phase with respect to the scanning produces a corresponding correction on the part of the brake.

The generation of a properly shaped filter disk is shown in Fig. 27. This shape is suitable for a receiving or transmitting tube with short decay or storage times. The curve obtained in Fig. 27 is an envelope of the position of a scanning line as traced on to the filter which is moving with the line. The required filter shape for a given mechanical arrangement is obtained by developing curves which make allowance for positive and negative tolerances to take care of fluctuation in the disk position, viewing angle, and screen decay (Fig. 28).

Generally, the minimum disk diameter is about twice the outside diameter of the tube plus one or two inches. The optimal location will be determined by such factors as the distance from the disk shaft to the picture frame, but can be determined for any particular arrangement.

Color-drums have been used at the receiver as well as at the transmitter instead of color-filters. A short cathode-ray tube can be placed within the drum (Fig. 29). The drum is designed for a lower speed of revolution than is usually possible with the disk. Successful drums have been built to operate at a speed of 600 rpm or one-half the usual disk speed.

The small table-model receiver shown in Fig. 23 utilizes a cathode-ray tube developed especially for color-pictures. The screen of the tube is flat and has the exact shape of the final image (Fig. 30). The tube produces a picture equivalent in size to that of a conventional 7-in. round tube. Thus the color disk is 15 in. in diameter. A 10-in. lens with a focal length of 12 in., which is built into the receiver, increases the image to correspond to that of a conventional 9-in. tube. Owing to low magnification, distortion and decrease of the viewing angle are appreciably reduced.

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NEW STOP BATH AND FIXING BATH FORMULAS AND METHODS FOR THEIR REVIVAL*

J. I. CRABTREE, L. E. MUEHLER, AND H. D. RUSSELL**

Summary.—*Several substitutes for acetic acid are recommended for use in acid stop baths and fixing baths including white vinegar, a mixture of sodium acetate and sodium acid sulfate, sodium bisulfite, and citric acid.*

Methods of testing stop baths to determine the exhaustion point are described and procedures given for their revival by the addition of acid.

A formula for a new rapid fixing bath is also given, including instructions for reviving fixing baths by the addition of acid at intervals.

In view of the requisition of many chemicals for defense purposes it may be impossible to secure in all parts of the country some essential photographic chemicals. An investigation has therefore been made with a view to making available a choice of chemicals to replace those ordinarily used in compounding stop baths and fixing baths.

STOP BATHS

Tests have indicated that for acid stop bath purposes a variety of acidic compounds may be substituted for the acetic acid usually employed, namely, a mixture of sodium acid sulfate or sulfuric acid and sodium acetate, citric acid, sodium bisulfite or potassium metabisulfite, and white vinegar.

Sodium Acid Sulfate and Sodium Acetate.—An almost identical substitute for the Kodak *SB-1* acid stop bath can be compounded from sodium acetate and an acidic substance such as sodium acid sulfate or sulfuric acid as follows:

Kodak SB-8 Stop Bath

	Avoirdupois	Metric
Water	64 ounces	500 cc
Kodak Sodium Acetate (desiccated)	2 oz 290 grains	20 grams
Kodak Sodium Acid Sulfate†	$5^1/_4$ ounces	40 grams
Water to make	1 gallon	1 liter

* Received January 14, 1942.

** Kodak Research Laboratories, Rochester, New York.

† ***OR*** Kodak Sulfuric Acid, 5% ($22^1/_2$ fluid oz per gallon; 175 cc per liter). To make 5 per cent sulfuric acid, add slowly 1 part by volume of Kodak Sulfuric Acid, C. P., to 19 parts by volume of cold water and mix carefully with stirring. The acid must be added *slowly to the water* and not the water to the acid, otherwise the solution may boil with explosive violence.

In the case of highly alkaline developers a somewhat more concentrated acid stop bath is necessary such as Kodak *SB-1a* which should preferably be used only in conjunction with Kodalk or caustic developers in order to avoid blistering. The stop bath should likewise be followed by a short water rinse. The formulas Kodak *SB-8a*, *SB-7a*, and *SB-6a* below are the more concentrated stop baths corresponding to *SB-8*, *SB-7*, and *SB-6*.

Kodak SB-8a Stop Bath

	Avoirdupois	Metric
Water	64 ounces	500 cc
Kodak Sodium Acetate (desiccated)	$6^3/_4$ ounces	50 grams
Kodak Sodium Acid Sulfate*	$13^1/_4$ ounces	100 grams
Water to make	1 gallon	1 liter

* ***OR*** Kodak Sulfuric Acid, 5% (56 fluid oz per gallon; 440 cc per liter). To make 5 per cent sulfuric acid, add slowly 1 part by volume of Kodak Sulfuric Acid, C. P., to 19 parts by volume of cold water and mix carefully with stirring. The acid must be added *slowly to the water* and not the water to the acid, otherwise the solution may boil with explosive violence.

Citric Acid.—A 1.5 per cent solution of citric acid constitutes a very satisfactory acid stop bath although, if an excess is carried over into the fixing bath, it tends to impair the hardening properties of the fixing bath.

The Kodak Testing Solution *A* for Stop Baths should be used to determine when the bath is exhausted. When exhausted, the bath should be discarded and a fresh bath prepared.

Suitable formulas are as follows:

Kodak SB-7 Stop Bath

	Avoirdupois	Metric
Kodak Citric Acid	2 ounces	15 grams
Water to make	1 gallon	1 liter

Kodak SB-7a Stop Bath

	Avoirdupois	Metric
Kodak Citric Acid	5 ounces	37.5 grams
Water to make	1 gallon	1.0 liter

Sodium Bisulfite.—As a substitute for the Kodak *SB-1* acid stop bath, the formula Kodak *SB-6* may be used, namely, 4 ounces per

gallon of Kodak Sodium Bisulfite. For Kodak *SB-1a* the proportion is 10 ounces of bisulfite per gallon (Kodak *SB-6a*) as follows:

Kodak SB-6 Stop Bath

	Avoirdupois	Metric
Kodak Sodium Bisulfite	4 ounces	30 grams
Water to make	1 gallon	1 liter

Kodak SB-6a Stop Bath

	Avoirdupois	Metric
Kodak Sodium Bisulfite	10 ounces	75 grams
Water to make	1 gallon	1 liter

White Vinegar.—White vinegar or distilled vinegar is a dilute solution of acetic acid, its strength varying from 3 to 15 per cent. The white vinegar sold in grocery stores in 1-gallon jugs is usually of 4.5 per cent acidity. The strength of vinegar is also designated by its "grain" content, 1 per cent acidity being approximately equal to 10-grain; therefore, a 45-grain vinegar represents a vinegar of 4.5 per cent acidity. Distilled vinegar containing 4 to 15 per cent acidity (40- to 150-grain) may be purchased from vinegar manufacturers or wholesale food supply houses in barrels.

For a substitute Kodak *SB-1* stop bath, dilute 1 part of white vinegar (4.5% = 45-grain) with 2 parts of water. As a substitute for the Kodak *SB-1a*, use white vinegar full strength.

Brown vinegar may be used instead of white vinegar but it is not as satisfactory. The odor is offensive and it tends to cause excessive foaming of the stop bath and fixing bath. This tendency to foam may, however, be decreased by the use of Kodak Anti-Foam Solution.

It is necessary that the acid stop bath remain acid throughout its life and the acidity can be checked by the use of the Kodak Testing Solution *A* for Stop Baths which may be used in either of two ways: (1) a small quantity of the stop bath is withdrawn and placed in a vial and the testing solution added to this; or (2) the indicator solution is added to the tray or tank containing the stop bath in the proportion indicated by the following table. When the bath turns purple, this is a signal that the bath should be discarded or revived.

All stop baths containing acetic acid, vinegar, sodium bisulfite (potassium metabisulfite), or sodium acetate and sodium acid sulfate may be renewed or revived with acid after the bath containing the indicator turns purple. The acid used in the revival may be any

Concentration of Kodak Testing Solution A for Stop Baths

TRAY

1 Quart or 1 Liter	2 Quarts or 2 Liters	1 Gallon or 4 Liters
1 cc	2 cc	4 cc
15 minims	30 minims	60 minims
1/4 dram	1/2 dram	1 dram
	1/4 vial	1/2 vial
		1/8 ounce

TANK

(White Card or Tray on Bottom of Tank)*

1 Gallon	3 1/2 Gallons
1/2 dram	2 drams
1/4 vial	1/4 ounce
	1 vial

* For larger tanks immerse the white tray or card to a depth of about 10 inches.

acidic compound which does not impair the properties of the bath. The common acids which are satisfactory include acetic acid, hydrochloric acid, sulfuric acid, and sodium acid sulfate. Boric acid and sodium bisulfite are not strong enough acids to give the proper reaction with the indicator solution unless they are added in excessive quantities. Citric acid, tartaric acid, and other hydroxy organic acids may be used in small quantities, otherwise, when the stop bath is carried into the fixing bath, the hardening properties of the fixing bath may be impaired.

Acid stop baths containing sodium bisulfite (potassium metabisulfite) need to be revived more frequently than the others because a 3 per cent solution of sodium bisulfite (potassium metabisulfite) has only one-third the developer life as indicated by the Kodak Testing Solution *A* for Stop Baths in comparison with the *SB-1* acetic acid stop bath.

REVIVAL OF STOP BATHS

The substitute acid stop baths can be revived in the following manner but they should be discarded whenever they become discolored or accumulate suspended matter:

(*1*) *Trays and Small Tanks.* Add 20 drops of Kodak Testing Solution *A* for Stop Baths to each quart (1 liter) of rinse bath. The indicator is yellow in the acid bath but turns purple when the acid has been neutralized If the indicator turns purple, the stop bath

may be revived by the addition of either the following formula, Kodak *SB-8R*, or a 5 per cent solution of sulfuric acid* with stirring. Add the acid slowly until the bath turns a light yellow color but do not add an excess of the acid.

Kodak SB-8R

	Avoirdupois	Metric
Kodak Sodium Acid Sulfate	3¼ ounces	97.5 grams
Water to make	32 ounces	1.0 liter

(*2*) *Deep Tanks.* Add 4 drams (15 cc.) of Kodak Testing Solution *A* for Stop Baths to each 10 gallons (40 liters) of the bath and place either a white card or a white tray in the bath such that the tray or card is immersed for a distance of about 10 inches to serve as a background for viewing the color of the bath. If the bath requires revival with acid, the solution will appear reddish purple in tungsten light. Add either a 5 per cent solution of sulfuric acid or the sodium acid sulfate revival bath, Kodak *SB-8R*, at the rate of 1 ounce per gallon until the purple color changes to light yellow, mixing the solution completely after each addition of acid. The indicator, after addition to the bath, may fade with time so that a fresh quantity should be added before each revival.

The Kodak Testing Solution *A* for Stop Baths may stain prints or films if they are left in the bath longer than 2 minutes. In this case it is advisable to test only a small portion of the bath with the test solution during revival of the bath with acid. In the test, fill the vial from the Kodak Testing Outfit within one-quarter inch of the top with the stop bath to be tested and add 1 drop of the Testing Solution *A* for Stop Baths; mix the solution by placing a finger over the open end of the vial and shaking the vial. If the solution turns purple, add Kodak *SB-8R* at the rate of 1 ounce per gallon and test the bath after each addition of acid. Continue adding acid to the bath (in the tank or tray) until a light yellow color is obtained, when 1 drop of test solution is added to the sample in the vial. Do not add an excess of acid.

The life of the regular acetic acid stop baths such as Kodak *SB-1*, Kodak *SB-1a*, and Kodak *SB-5* may also be prolonged by the ad-

* To make 5 per cent sulfuric acid, add slowly 1 part by volume of Kodak Sulfuric Acid, C. P., to 19 parts by volume of cold water and mix carefully with stirring. The acid must be added *slowly to the water* and not the water to the acid, otherwise the solution may boil with explosive violence.

dition of Kodak *SB-8R*, according to the above procedure. The Kodak *SB-5* Stop Bath containing acetic acid and an anti-swelling agent (sodium sulfate) is recommended exclusively for use with film. When used at normal temperatures, the bath may be revived with acid at frequent intervals but the sulfate becomes diluted, which impairs the usefulness of the bath at high temperatures. When the bath is used at high temperatures, it tends to become discolored and accumulates a sludge more readily which, unless filtered or siphoned off, may adhere to the film. It is desirable, therefore, to renew the bath frequently. Other stop baths should be discarded after they have been revived 3 or 4 times or when they become discolored.

Formulas for 1-liter, 1-gallon, 17-gallon, and 48-gallon quantities of the Kodak *SB-6*, *SB-7*, and *SB-8* stop baths are given in Table I.

Substitutes for Non-Swelling Stop Bath SB-5.—In compounding a substitute for the Kodak non-swelling acid stop bath *SB-5* add to any of the above stop bath formulas sodium sulfate (desiccated) in the proportions given below:

Volume of Stop Bath	Quantity of Sodium Sulfate (Desiccated) Required
1 liter	45 grams
1 gallon	6 ounces
17 gallons	6 lb 6 ounces
48 gallons	18 lb

Add the desiccated sodium sulfate slowly with stirring, otherwise the sulfate will cake and then dissolve with difficulty.

Revival of Chrome Alum Stop Baths.—The chrome alum stop baths Kodak *SB-3* and Kodak *SB-4* can not be revived by the above procedure using the Kodak Testing Solution *A* for Stop Baths. The revival of a chrome alum bath is more complicated than that in the case of an acetic acid bath, because of several peculiar properties of chrome alum solutions. The *p*H value of a freshly prepared chrome alum solution is approximately 3.0 and the maximum hardening properties in the fresh solution are obtained between *p*H values of 3.0 and 4.0. With slight use when a small quantity of developer is carried into the stop bath, the *p*H value increases but, on standing, the solution undergoes a change in an attempt to adjust itself to its original *p*H value of 3.0. This change involves the formation of basic chromium complexes with the liberation of sulfuric acid. The presence of basic chromium complexes increases the sludging and scumming

TABLE I

Kodak Substitute Stop Baths

Kodak SB-6 Stop Bath

TO MAKE:	1 Gallon	17 Gallons	48 Gallons	1 Liter
Kodak Sodium Bisulfite	4 ounces	4 1/4 pounds	12 pounds	30 grams
Water to make	1 gallon	17 gallons	48 gallons	1 liter
Kodak SB-7 Stop Bath				
Kodak Citric Acid	2 ounces	2 lb 2 ounces	6 pounds	15 grams
Water to make	1 gallon	17 gallons	48 gallons	1 liter
Kodak SB-8 Stop Bath				
Water	64 ounces	8 gallons	24 gallons	500 cc
Kodak Sodium Acetate (desiccated)	2 oz 290 grains	2 3/4 pounds	8 pounds	20 grams
Kodak Sodium Acid Sulfate*	5 1/4 ounces	5 3/4 pounds	16 pounds	40 grams
Water to make	1 gallon	17 gallons	48 gallons	1 liter

* ***OR*** Kodak Sulfuric Acid, 5% (22 1/2 fluid oz per gallon; 175 cc per liter). To make 5 per cent sulfuric acid, add slowly 1 part by volume of Kodak Sulfuric Acid, C. P., to 19 parts by volume of cold water and mix carefully with stirring. The acid must be added *slowly to the water*, and not the water to the acid, otherwise the solution may boil with explosive violence.

tendency of the bath and, if the bath is used only occasionally, the bath may suddenly sludge or produce an undesirable scum on the film. This condition of the bath can not be readily determined since the *p*H value of the solution may be similar to that of the fresh bath and revival with acid will not restore it to its original condition. Therefore, it is recommended that if a chrome alum stop bath is to be used at infrequent intervals, only a fresh bath should be used.

Chrome alum baths which are in continuous use may be satisfactorily revived if the rate of exhaustion is such that they would normally be exhausted within a 24-hour period. In this case the condition of the bath is best determined by the use of a glass-electrode *p*H meter and the bath should be revived at frequent intervals to a *p*H value of 3.0 by the addition of a 5 per cent solution of sulfuric acid or Kodak *SB-8R*.

The condition of the bath may also be determined by titrating a 25-cc sample of the bath (in 50 cc of distilled water containing 5 cc of a 1 : 2500 solution of bromophenol blue indicator) with a solution of sulfuric acid (2.5%) or Kodak *SB-8R* until the solution is just acid to the indicator. The indicator solution is blue at a *p*H value of 4.0 and yellow at a value of 3.0, but the color is somewhat obscured by the green color of the chrome alum solution. The color in an acid chrome alum solution will be yellowish green and, in an alkaline solution, a dirty blue.

From the quantity of acid required in the titration for 25 cc of the stop bath, the quantity for the entire bath can be calculated. One cubic centimeter of a 2.5 per cent solution of sulfuric acid per 25 cc of the bath will require the addition of 2.5 ounces per gallon of 5 per cent sulfuric acid. One cubic centimeter of Kodak *SB-8R* per 25 cc of the bath will require the addition of 5 ounces of Kodak *SB-8R* per gallon.

The above test may be modified as follows to permit the use of methyl orange instead of the bromophenol blue indicator if the latter is not readily available: Dilute a 25-cc sample of the used *SB-3* stop bath to 250 cc with water and then add 15 cc of a solution of methyl orange indicator prepared by dissolving 1 gram in 2500 cc of water. If the bath requires replenishment the test solution will be lemon-yellow. Titrate as described above with acid. An orange-pink or peach color indicates the correct degree of revival but, if too much acid is added, the color will be rose-pink.

Testing the Strength of Acetic Acid Solutions.—Acetic acid is sold

in a variety of strengths and, in case the precise strength is unknown it can be determined approximately by the following procedure:

Prepare a standard solution of Kodalk by dissolving 3 ounces (85 grams) in 20 ounces (600 cc) of water. Then carefully add water to make 26 ounces (770 cc), stir to obtain complete uniformity, and place in a closed quart bottle.

When measuring liquids, the reading of the graduate should be taken from the lowest part of the curved surface of the liquid (meniscus) with the eye held at the same level.

In a clean 1-ounce graduate standing on a level surface carefully measure exactly 0.5 ounce of the acetic acid solution, the percentage strength of which is unknown. Add this to a previously washed 16- or 32-ounce graduate standing on a white surface, for example, in a white enameled tray. Add 3 to 4 ounces of water, stir with a clean stirring rod and follow with 5 drops of the Kodak Testing Solution *A* for Stop Baths. The purple indicator will change to yellow in the acid solution.

Carefully measure 12 ounces of the Kodalk solution into a 16-ounce graduate standing on a level surface. Slowly add the Kodalk solution (avoid spillage) to the acetic acid solution containing the indicator while stirring with a clean stirring rod, and carefully observe the color. When nearing the neutralization point, the color will change to a dirty yellow, then to a gray, and finally to a distinct permanent red-violet. When just sufficient Kodalk solution has been added to cause the color to change to red-violet, set the graduate on a level surface and read the remaining volume in ounces. Subtract this number of ounces from the 12 ounces originally taken to determine the number of ounces (including fraction) used to neutralize the acid. Multiply the number of ounces used by 10 to give the percentage strength of the acetic acid.

As an example, the original volume of Kodalk solution was 12 ounces and the final volume 4 ounces. Therefore, 12 ounces minus 4 ounces = 8 ounces of standard Kodalk solution used. Acetic acid strength = $8 \times 10 = 80$ per cent.

The accuracy of the determination depends principally upon the care used. For medium and high percentages of acid the method has been found to give results to within about 5 per cent of the acetic acid strength.

For lower-strength acid (5 to 30 per cent) better accuracy is obtained when the starting volume of the Kodalk solution is 4 ounces

instead of 12. In this case subtract the remaining volume of the Kodalk solution in ounces from 4 to give the volume used. For example:

Original volume of Kodalk solution	4 ounces
Final volume of Kodalk solution	2 ounces
Volume of Kodalk solution used	2 ounces
Acetic acid strength = 2 × 10 =	20 per cent

For best accuracy with acid strengths of the order of 5 per cent or less, use 1 ounce of the Kodalk solution in a 1-ounce graduate. Determine the fraction of an ounce used and multiply this by 10. For example:

1 minus $^1/_4$ = $^3/_4$ ounce of standard Kodalk solution used, and
$^3/_4$ × 10 = $7^1/_2$ per cent acetic acid

FIXING BATHS

The desirable hardening and anti-sludging properties of acid-hardening fixing baths containing acetic and boric acids can not be duplicated by other readily available acids. Propionic acid is a suitable substitute for acetic acid but it is available commercially in only small quantities.

However, acetic acid can be replaced satisfactorily by sodium acetate in combination with another acidic compound such as sodium bisulfite or sodium acid sulfate. White vinegar can also be used as a substitute for acetic acid in formulas Kodak *F-1*, *F-5*, *F-6*, and *F-10*.

The hardening and fixing-bath formulas Kodak *F-1* and *F-5* which are most commonly used require normally 6 ounces of 28 per cent acetic acid per gallon. In these formulas 40 ounces of white vinegar should be substituted for the 6 ounces of 28 per cent acetic acid.

The acid-hardening stock solutions Kodak *F-1a* (*V*) and *F-5a* (*V*) are given in Tables II and III. *Important:* These hardening formulas must be added to a 48 per cent solution of hypo which is roughly 4 pounds of hypo contained in 1 gallon of solution.

The baths Kodak *F-3*, *F-3a*, *F-4*, and *F-4a*, containing sodium acetate, together with a suitable acid compound, such as sodium bisulfite or sodium acid sulfate, have properties very similar to those of *F-5*.

A formula having properties similar to those of the odorless bath Kodak *F-6* can be compounded by substituting 2 parts of Kodalk for 1 part of boric acid in Kodak *F-5* (*V*) or Kodak *F-3* described

TABLE II

Kodak Substitute Fixing Bath

Kodak F-1 (V)

		Avoirdupois		Metric
TO MAKE	1 Gallon	45 Gallons	48 Gallons	1 Liter
Water (about 125°F) (50°C)	64 ounces	22½ gallons	24 gallons	500 cc
Kodak Sodium Thiosulfate (Hypo)	2 pounds	90 pounds	96 pounds	240 grams
Kodak Sodium Sulfite (desiccated)	2 ounces	5¾ pounds	6 pounds	15 grams
Vinegar (4.5%) 45-grain	40 fluid oz	14 gallons	15 gallons	310 cc
Kodak Potassium Alum	2 ounces	5¾ pounds	6 pounds	15 grams
Water to make	1 gallon	45 gallons	48 gallons	1 liter

Kodak Substitute Stock Solution

Kodak F-1a (V)

		Avoirdupois		Metric
TO MAKE	1 Gallon	22½ Gallons	24 Gallons	1 Liter
Water (about 125°F) (50°C)	32 ounces	5½ gallons	6 gallons	250 cc
Kodak Sodium Sulfite (desiccated)	4 ounces	5¾ pounds	6 pounds	30 grams
Vinegar (4.5%) 45-grain	80 fluid oz	14 gallons	15 gallons	620 cc
Kodak Potassium Alum	4 ounces	5¾ pounds	6 pounds	30 grams
Water to make	1 gallon	22½ gallons	24 gallons	1 liter

To prepare Kodak *F-1 (V)* from *F-1a (V)* add 1 part of cool stock hardener solution *F-1a (V)* slowly to 1 part of cool 48 per cent hypo solution while stirring the hypo rapidly, or use the quantities indicated as follows:

Kodak Substitute Fixing Bath

Kodak F-1 (V)

		Avoirdupois		Metric
TO MAKE	1 Gallon	45 Gallons	48 Gallons	1 Liter
Water (about 125°F) (50°C)	42 ounces	15 gallons	16 gallons	330.0 cc
Kodak Sodium Thiosulfate (Hypo)	2 pounds	90 pounds	96 pounds	240.0 grams

When the hypo is dissolved, add the following quantity of Kodak *F-1a (V)* stock hardener:

Hardener *F-1a (V)*	½ gallon	22½ gallons	24 gallons	500.0 cc
Add water to make	1 gallon	45 gallons	48 gallons	1.0 liter

below. Formula Kodak *F-6* is to be preferred to Kodak *F-5* for use in trays because the odor of sulfur dioxide is very much less. Kodak *F-6* is recommended especially for papers but may also be used with

TABLE III

Kodak Substitute Fixing Bath

Kodak F-5 (V)

	Avoirdupois		Metric
TO MAKE	1 Gallon	45 Gallons	48 Gallons	1 Liter
Water (about 125°F) (50°C)	64 ounces	22½ gallons	24 gallons	500.0 cc
Kodak Sodium Thiosulfate (Hypo)	2 pounds	90 pounds	96 pounds	240.0 grams
Kodak Sodium Sulfite (desiccated)	2 ounces	5¾ pounds	6 pounds	15.0 grams
*Kodak Boric Acid, crystals	1 ounce	2¾ pounds	3 pounds	7.5 grams
Vinegar (4.5%) 45-grain	40 fluid oz	14 gallons	15 gallons	310.0 cc
Kodak Potassium Alum	2 ounces	5¾ pounds	6 pounds	15.0 grams
Water to make	1 gallon	45 gallons	48 gallons	1.0 liter

* Use crystalline boric acid as specified; avoid use of the powdered variety which dissolves slowly.

Kodak Substitute Stock Solution

Kodak F-5a (V)

	Avoirdupois		Metric
TO MAKE	1 Gallon	22½ Gallons	24 Gallons	1 Liter
Water (about 125°F) (50°C)	32 ounces	5½ gallons	6 gallons	250 cc
Kodak Sodium Sulfite (desiccated)	4 ounces	5¾ pounds	6 pounds	30 grams
Vinegar (4.5%) 45-grain	80 fluid oz	14 gallons	15 gallons	620 cc
*Kodak Boric Acid, crystals	2 ounces	2¾ pounds	3 pounds	15 grams
Kodak Potassium Alum	4 ounces	5¾ pounds	6 pounds	30 grams
Water to make	1 gallon	22½ gallons	24 gallons	1 liter

* Use crystalline boric acid as specified; avoid use of the powdered variety which dissolves slowly.

To prepare Kodak *F-5* (*V*) from *F-5a* (*V*) add 1 part of cool stock hardener solution slowly to 1 part of cool 48 per cent hypo solution while stirring the hypo rapidly, or use the quantities indicated in Table IV.

films if used in combination with an acid stop bath. The acid life of Kodak *F-6* is approximately only one-half that of Kodak *F-5* but, by using an intermediate acid stop bath, the life may be extended

greatly. The formulas Kodak *F-3*, *F-3a*, *F-4*, and *F-4a* are given in Tables V and VI.

A New Rapid Fixing Bath.—A fixing bath (Kodak *F-7*) having a greater fixing capacity than Kodak *F-5* has been compounded by the use of ammonium chloride in combination with a relatively high concentration of hypo, together with the hardener constituents of Kodak *F-5*. Kodak *F-8* is a hypo solution containing ammonium chloride which can be used in combination with hardeners Kodak *F-5a* and the substitutes for Kodak *F-5a*, namely, Kodak *F-3a* and *F-4a*, to produce a fixing bath having properties similar to those of Kodak *F-7*. Kodak *F-8* is not sufficiently concentrated to be used with *F-5a* (*V*) but a fixing bath containing vinegar can be com-

TABLE IV

Kodak Substitute Deep Tank Fixing Bath

***Kodak F-5* (*V*)**

		Avoirdupois		Metric
TO MAKE	1 Gallon	45 Gallons	48 Gallons	1 Liter
Water (about 125°F) (50°C)	42 ounces	15 gallons	16 gallons	330 cc
Kodak Sodium Thiosulfate (Hypo)	2 pounds	90 pounds	96 pounds	240 grams
When the hypo is dissolved, add the following quantity of Kodak *F-5a* (*V*) Stock Hardener:				
Hardener *F-5a* (*V*)	1/2 gallon	22 1/2 gallons	24 gallons	500 cc
Add water to make	1 gallon	45 gallons	48 gallons	1 liter

pounded similar to formula *F-7* by adding the hypo, ammonium chloride, and sodium sulfite to one-half the usual quantity of water, adding the vinegar before they are all dissolved, then adding the boric acid and alum, diluting to volume with water and stirring until dissolved.

When compounding the formulas, the ammonium chloride should be added to the hypo solution and not to the final fixing solution containing the hardener, otherwise a sludge may form.

The formula Kodak *F-7* (Table VII) is recommended especially for use in the machine processing of negative films. It can also be used for papers but has no advantage over other formulas which do not contain ammonium chloride. With papers it should invariably be used in conjunction with an acid stop bath, otherwise, if the bath becomes alkaline, dichroic fog is apt to be produced.

TABLE V

Kodak Substitute Acid Hardening-Fixing Bath

Kodak F-3

	Avoirdupois			Metric
TO MAKE	1 Gallon	45 Gallons	48 Gallons	1 Liter
Water (about 125°F) (50°C)	64 ounces	22½ gallons	24 gallons	500.0 cc
Kodak Sodium Thiosulfate (Hypo)	2 pounds	90 pounds	96 pounds	240.0 grams
Kodak Sodium Bisulfite	2 ounces	5¾ pounds	6 pounds	15.0 grams
*Kodak Boric Acid, crystals	1 ounce	2¾ pounds	3 pounds	7.5 grams
Kodak Sodium Acetate (desiccated)	2 oz 290 grains	7½ pounds	8 pounds	20.0 grams
**Kodak Sodium Acid Sulfate (20% solution)	9½ fluid oz	3 gal 45 oz	3 gal 72 oz	75.0 cc.
Kodak Potassium Alum	2 ounces	5¾ pounds	6 pounds	15.0 grams
Water to make	1 gallon	45 gallons	48 gallons	1.0 liter

* Use crystalline boric acid as specified; avoid use of the powdered variety which dissolves slowly.

** Dissolve 200 grams (6¾ ounces) of sodium acid sulfate in 750 cc (24 oz) of water and add cold water to make 1 liter (32 oz). The sodium acid sulfate must be added slowly and as a solution, otherwise the fixing bath will sulfurize.

Kodak Substitute Acid Hardener Stock Solution

Kodak F-3a

TO MAKE	1 Gallon	5 Gallons	10 Gallons	1 Liter
Water (about 125°F) (50°C)	80 ounces	3 gallons	6 gallons	600.0 cc
Kodak Sodium Bisulfite	10 ounces	3 lb 2 oz	6¼ pounds	75.0 grams
*Kodak Boric Acid, crystals	5 ounces	1 lb 9 oz	3 lb 2 oz	37.5 grams
Kodak Sodium Acetate (desiccated)	13¼ ounces	4 lb 3 oz	8 lb 6 oz	100.0 grams
Kodak Sodium Acid Sulfate	10 ounces	3 lb 2 oz	6¼ pounds	75.0 grams
Kodak Potassium Alum	10 ounces	3 lb 2 oz	6¼ pounds	75.0 grams
Water to make	1 gallon	5 gallons	10 gallons	1.0 liter

* Use crystalline boric acid as specified; avoid use of the powdered variety which dissolves slowly.

Add 1 part of cool stock hardener solution slowly to 4 parts of a cool 30 per cent hypo solution while stirring the hypo rapidly.

TABLE VI

Kodak Substitute Acid Hardening-Fixing Bath

Kodak F-4

	Avoirdupois			Metric
TO MAKE	1 Gallon	45 Gallons	48 Gallons	1 Liter
Water (about 125°F) (50°C)	64 ounces	22½ gallons	24 gallons	500.0 cc
Kodak Sodium Thiosulfate (Hypo)	2 pounds	90 pounds	96 pounds	240.0 grams
Kodak Sodium Bisulfite	3 oz 145 grains	9¼ pounds	10 pounds	25.0 grams
*Kodak Boric Acid, crystals	1 ounce	2¾ pounds	3 pounds	7.5 grams
Kodak Sodium Acetate (desiccated)	2 oz 290 grains	7½ pounds	8 pounds	20.0 grams
Kodak Potassium Alum	2 ounces	5¾ pounds	6 pounds	15.0 grams
Water to make	1 gallon	45 gallons	48 gallons	1.0 liter

* Use crystalline boric acid as specified; avoid use of the powdered variety which dissolves slowly.

Kodak Substitute Acid Hardener Stock Solution

Kodak F-4a

TO MAKE	1 Gallon	5 Gallons	10 Gallons	1 Liter
Water (about 125°F) (50°C)	80 ounces	3 gallons	6 gallons	600.0 cc
Kodak Sodium Bisulfite	16¾ ounces	5 lb 3 oz	10 lb 6 oz	125.0 grams
*Kodak Boric Acid, crystals	5 ounces	1 lb 9 oz	3 lb 2 oz	37.5 grams
Kodak Sodium Acetate (desiccated)	13¼ ounces	4 lb 3 oz	8 lb 6 oz	100.0 grams
Kodak Potassium Alum	10 ounces	3 lb 2 oz	6¼ pounds	75.0 grams
Water to make	1 gallon	5 gallons	10 gallons	1.0 liter

* Use crystalline boric acid as specified; avoid use of the powdered variety which dissolves slowly.

Add 1 part of cool stock hardener solution slowly to 4 parts of a cool, 30 per cent hypo solution while stirring the hypo rapidly.

Note: In the above baths, Kodak *F-3*, *F-3a*, *F-4* and *F-4a*, if boric acid is not available, use one-third the quantity of Rochelle Salts in place of boric acid. However, the hardening properties and sludge life of the baths containing Rochelle Salts are inferior to those of the baths containing boric acid.

TABLE VII

A Rapid Fixing Bath Containing Ammonium Chloride for General Photographic Use

Kodak F-7*

	Avoirdupois			Metric
TO MAKE	1 Gallon	45 Gallons	48 Gallons	1 Liter
Water (about 125°F) (50°C)	80 ounces	30 gallons	32 gallons	600.0 cc
Kodak Sodium Thiosulfate (Hypo)	3 pounds	135 pounds	144 pounds	360.0 grams
Kodak Ammonium Chloride	6 3/4 ounces	18 3/4 pounds	20 pounds	50.0 grams
Kodak Sodium Sulfite (desiccated)	2 ounces	5 3/4 pounds	6 pounds	15.0 grams
Kodak Acetic Acid (28%)	6 fluid oz	2 gal 14 oz	2 1/4 gallons	48.0 cc
**Kodak Boric Acid, crystals	1 ounce	2 3/4 pounds	3 pounds	7.5 grams
Kodak Potassium Alum	2 ounces	5 3/4 pounds	6 pounds	15.0 grams
Water to make	1 gallon	45 gallons	48 gallons	1.0 liter

* The hardener constituents of Kodak *F-7* are the same as those of Kodak *F-5*.

** Use crystalline boric acid as specified; avoid use of the powdered variety which dissolves slowly.

The following stock hypo solution may be used in conjunction with Kodak *F-5a*, *F-4a*, or *F-3a:*

Kodak F-8

TO MAKE	1 Gallon	45 Gallons	48 Gallons	1 Liter
Water (about 125°F) (50°C)	64 ounces	22 1/2 gallons	24 gallons	500.0 cc
Kodak Sodium Thiosulfate (Hypo)	3 pounds	135 pounds	144 pounds	360.0 grams
Kodak Ammonium Chloride	6 3/4 ounces	18 3/4 pounds	20 pounds	50.0 grams

When the hypo and ammonium chloride are dissolved completely, add the following quantity of Stock Hardener solution mixed according to formulas Kodak *F-5a*, *F-4a*, or *F-3a:*

Hardener	26 ounces	9 gallons	9 3/4 gallons	200.0 cc.
Add water to make	1 gallon	45 gallons	48 gallons	1.0 liter

TABLE VIII

Hardening Properties of Various Fixing Baths Containing Ammonium Chloride at 70° F

% MQ-25	*Kodak F-5*	*Kodak F-7*	*Kodak F-3*	*Kodak F-8 + Kodak F-3a*	*Kodak F-4*	*Kodak F-8 + Kodak F-4a*
0	>212°F	>212°F	>212°F	>212°F	210°F	200°F
10	>212°F	>212°F	>212°F	210°F	200°F	190°F
20	>212°F	210°F	210°F	180°F	180°F	160°F
30	210°F	190°F	200°F	140°F	160°F	140°F
40	140°F	130°F	130°F	100°F	120°F	100°F
60	100°F	100°F	100°F	100°F	100°F	100°F
80	100°F (S)	100°F (S)	100°F (S)	100°F (S)	100°F (S)	100°F (S)

S = Sludged within 24 hours.

The advantages of this formula are that (*1*) the time to clear most negative films is less than that for Kodak *F-5*, and that (*2*) the fixation life is approximately 50 per cent greater than that of Kodak *F-5*.

A comparison of the hardening properties* of the fixing baths Kodak *F-3*, *F-4*, and *F-5* with and without increased hypo plus 5 per cent ammonium chloride is given in Table VIII. The results indicate that the addition of ammonium chloride decreases the hardening properties slightly, that is, the melting point in most cases is 10° to 30°F lower than in the bath containing only 24 per cent hypo. The sludge life was not affected and was equivalent to 80 per cent of *MQ-25* developer.**

The effect of exhaustion on the time to clear Panatomic-*X* Roll Film was determined in *F-5* and in *F-5* containing additional hypo and ammonium chloride (Kodak *F-7*). Throughout the exhaustion Panatomic-*X* Roll Film was developed in *DK-60a*, rinsed in *SB-5*, and fixed. The times to clear after 0, 40, 80, and 120 rolls (area of roll approx. 80 sq in.) per gallon had been processed in *F-5* were $5^1/_4$, 7 11, and > 30 minutes, respectively, while the times to clear in *F-7* were $1^1/_2$, $2^1/_4$, 5, and $8^1/_2$ minutes, respectively, as shown in Table IX.

TABLE IX

Effect of Exhaustion on the Time to Clear Panatomic-X NC Film at 70°F

Degree of Exhaustion (No. of Rolls per Gallon)	*Kodak F-5*	*Kodak F-7*
0	$5^1/_4$ min	$1^1/_2$ min
40	7 min	$2^1/_4$ min
80	11 min	5 min
120	> 30 min	$8^1/_2$ min

An advantage similar to that given by Kodak *F-7* is obtained when Kodak *F-8* is used in combination with hardeners Kodak *F-3a* and *F-4*.

* The degree of hardening was determined in a manner similar to that described in the paper, "Some Properties of Fixing Baths," by J. I. Crabtree and H. A. Hartt, *Trans. Soc. Mot. Pict. Eng.*, **XIII**, No. 38 (1929), p. 370.

***MQ-25*

Elon	1.0 gram
Hydroquinone	4.0 grams
Sodium sulfite, desiccated	75.0 grams
Sodium carbonate, desiccated	25.0 grams
Potassium bromide	5.0 grams
Water to make	1.0 liter

TABLE X

Effect of Exhaustion with Acid Revival on the Hardening Properties of Kodak F-7

Degree of Exhaustion (No. of Rolls per Gallon)	Degree of Hardening	
	Before Revival	After Revival
0	> 212°F	> 212°F
40	200°F	> 212°F
80	190°F	200°F
120	160°F	180°F

The effect of exhaustion on the time to clear in formulas Kodak *F-4* and *F-3* was similar to that obtained with Kodak *F-5*. The effect of exhaustion with formula *F-7* compounded with the substitute hardeners Kodak *F-3a* and *F-4a* was similar to that obtained with Kodak *F-7*.

Revival of Fixing Baths.—A fixing bath is usually discarded for one or more of the following reasons: (*a*) it sludges, (*b*) it does not harden satisfactorily, (*c*) the time of fixation is excessive, or (*d*) it is muddy or stains the photographic material.

In order to obtain the greatest possible use from the fixing bath, the acidity of the bath should be maintained relatively constant so that the hardening and sludging properties will not be impaired before the fixing power of the hypo is exhausted.

Any of the above fixing baths containing boric acid may be revived with acid, using the Kodak Testing Solution *A* for Stop Baths in exactly the same manner as described above for rinse baths. Suitable acidic materials for revival purposes are (*1*) 28 per cent acetic acid, (*2*) sodium acid sulfate (Kodak *SB-8R*), or (*3*) 5 per cent sulfuric acid. Acids such as citric or tartaric are not suitable since they impair the hardening properties of the fixing bath. Also, sodium bisulfite is insufficiently acid for the purpose.

Acetic acid is preferred for reviving fixing baths because a slight excess will not impair the properties and there is less tendency toward sulfurization. In all cases when reviving fixing baths with acid, the diluted acid should be added *slowly with stirring* in order to prevent sulfurization of the hypo.

The effect of exhaustion with acid revival on the hardening properties of Kodak *F-7* is shown in Table X. In this test Verichrome film was developed in *MQ-25* and fixed without rinsing. The acidity of the bath was then revived with 28 per cent acetic acid after 40 rolls per gallon had been processed and the hardening determined.

After an additional 40 rolls were processed the bath was again revived with acid and the hardening determined. Another 40 rolls were processed, making a total of 120 rolls per gallon, and the bath was again revived with acid. Samples of the bath at each stage were taken before and after revival and the hardening was determined. The results indicate that the degree of hardening decreased from a value greater than 212° to 200°F before revival, after processing 40 rolls per gallon. The hardening increased to more than 212°F after revival with acid, and then decreased to 190°F after another 40 rolls per gallon were processed. After again reviving with acid, the hardening increased to 200°F and then decreased to 160°F during the processing of another 40 rolls per gallon. After revival with acid the degree of hardening was 180°F. Kodak *F-8* in combination with hardeners Kodak *F-3a* and *F-4a* could be revived in the same manner and the results would be similar to those obtained with Kodak *F-7*.

Although these tests indicate that the acidity of a fixing bath can be satisfactorily maintained by revival, it is considered better practice to use an intermediate acid stop bath and to maintain its acidity constant rather than to add acid to the fixing bath.

Fixing baths used for paper should be tested with the Testing Solution *B* of the Kodak Testing Outfit and discarded when a positive test is obtained.

Revival of a used fixing bath with hypo and hardener is not generally recommended, however, unless the photographer has available apparatus for adequate chemical analysis and the removal of silver.

Choice of Acid Substitutes.—The particular acid substitute which each individual consumer may wish to use will depend upon what chemicals are most readily available in his vicinity. The suggested order of preference is as follows:

(*A*) *Stop Baths*
- (*1*) Vinegar (white)
- (*2*) Sodium acetate with sodium acid sulfate
- (*3*) Sodium bisulfite
- (*4*) Citric acid

(*B*) *Fixing Baths*
- (*1*) Vinegar (white)
- (*2*) Sodium acetate and sodium acid sulfate
- (*3*) Sodium bisulfite

BOOK REVIEW

Photography: Its Science and Practice. John R. Roebuck and Henry C. Staehle, *D. Appleton-Century Company* (New York, N. Y.), 1942.

The present book is an outgrowth of one originally prepared by Professor Roebuck for use in a course in photography in the Physics Department of the University of Wisconsin about 1916. In view of the many advances that have been made in the art since that time, it became necessary for Professor Roebuck, with the aid of Dr. Henry C. Staehle of the Research Laboratories of the Eastman Kodak Co., to rewrite the book completely.

The result of this collaboration is a highly commendable and valuable addition to the photographic literature. It will prove valuable both to amateurs and experts, in providing an overall view of the photographic process, without going too deeply into technicalities. There are, in addition, thousands of persons who make photography their hobby and have acquired a considerable grasp of the technics of photography, and yet require information on the scientific fundamentals of the subject. It is for such persons that the book is primarily intended.

The whole of the modern science of photography is surveyed. A brief sketch of the historical development of photography leads to a study of the nature of the photographic emulsion and the manner in which an image is produced. Attention is next given to the properties of photographic materials in relation to their reaction to light, the factors determining correct exposure, and the sensitivity to color needed to preserve tonal values. The chemical processes of development are then treated, followed by a study of positive processes such as printing, enlarging, making lantern-slides, and reproduction for the graphic arts. The chapter on latent-image theory presents the latest views on the mechanism of image formation, and another chapter is devoted to lenses and the optical aspects of photography. Modern processes of color photography are outlined, and the final chapter gives a concise presentation of the subject of pictorial composition and aids in making good pictures. The last section of the book forms a brief laboratory manual consisting of a series of practical experiments.

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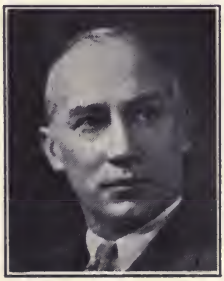

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H. BARNETT
C. N. BATSEL
M. C. BATSEL
F. T. BOWDITCH
M. R. BOYER
F. E. CARLSON
T. H. CARPENTER
E. K. CARVER
H. B. CUTHBERTSON
L. W. DAVEE
J. A. DUBRAY
A. F. EDOUART
J. L. FORREST
A. N. GOLDSMITH
H. GRIFFIN
A. C. HARDY
C. R. KEITH
P. J. LARSEN
R. LINDERMAN
C. L. LOOTENS
J. A. MAURER
G. S. MITCHELL
W. H. OFFENHAUSER
G. F. RACKETT
W. B. RAYTON
H. RUBIN
O. SANDVIK
H. E. WHITE

Studio Lighting

R. LINDERMAN, *Chairman*

J. W. BOYLE
R. E. FARNHAM
K. FREUND
C. W. HANDLEY
D. B. JOY
A. RODGERS
K. STRAUSS

Television

P. C. GOLDMARK, *Chairman*

H. BAMFORD
R. L. CAMBPELL
E. D. COOK
C. E. DEAN
J. B. ENGL
A. N. GOLDSMITH
T. T. GOLDSMITH
H. GRIFFIN
A. C. JENSEN
P. J. LARSEN
H. B. LUBCKE
I. G. MALOFF
J. A. MAURER
P. MERTZ
A. MURPHY
O. SANDVIK
R. E. SHELBY
H. E. WHITE

Theater Engineering

A. N. GOLDSMITH, *Chairman*

Projection Practice Sub-Committee
C. F. HORSTMAN, *Sub-Chairman*

H. ANDERSON
T. C. BARROWS
H. D. BEHR
K. BRENKERT
F. E. CAHILL, JR.
C. C. DASH
A. S. DICKSINON
J. K. ELDERKIN
J. FRANK, JR.
R. R. FRENCH
E. R. GEIB
M. GESSIN
A. GOODMAN
H. GRIFFIN
S. HARRIS
J. J. HOPKINS
L. B. ISAAC
I. JACOBSEN
J. H. LITTENBERG
E. R. MORIN
J. R. PRATER
F. H. RICHARDSON
H. RUBIN
J. J. SEFING
R. O. WALKER
V. A. WELMAN
H. E. WHITE
A. T. WILLIAMS

Theater Design Sub-Committee
B. SCHLANGER, *Sub-Chairman*

F. W. ALEXA
J. R. CLARK
E. EBERSON
J. FRANK, JR.
M. M. HARE
S. HARRIS
C. F. HORSTMAN
E. R. MORIN
A. L. RAVEN
J. J. SEFING

Screen Brightness Sub-Committee
F. E. CARLSON, *Sub-Chairman*

H. BARNETT
E. R. GEIB
S. HARRIS
W. F. LITTLE
W. B. RAYTON
C. TUTTLE
H. E. WHITE
A. T. WILLIAMS

SMPE REPRESENTATIVES TO OTHER ORGANIZATIONS

American Documentation Institute	J. E. ABBOTT
Sectional Committee on Motion Pictures, ASA	E. K. CARVER A. N. GOLDSMITH H. G. TASKER
Sectional Committee on Photography, ASA	J. I. CRABTREE
Inter-Society Color Council	R. M. EVANS J. A. BALL F. T. BOWDITCH G. F. RACKETT
Sectional Committee on Standardization of Letter Symbols and Abbreviations for Science and Engineering, ASA	L. A. JONES
National Association of Broadcasters, Committee on Recording and Reproducing Standards	R. M. MORRIS

American Standards Association
Sectional Committee on Motion Pictures (Z22)

ALFRED N. GOLDSMITH, *Chairman*
SYLVAN HARRIS, *Chairman*

J. O. AALBERG
P. H. ARNOLD
M. C. BATSEL
C. R. BROWN
B. H. CARROLL
E. K. CARVER
KENNETH CLARK
W. CLARK
A. S. DICKINSON
J. A. DUBRAY
F. EDOUART
E. W. ELY
R. E. FARNHAM
H. GRIFFIN
R. G. HOLSLAG
L. A. JONES
D. B. JOY
*(E. A. WILLIFORD)
C. R. KEITH
G. A. MITCHELL
*(J. RUTTENBERG)
G. S. MITCHELL
O. F. NEU
N. F. OAKLEY
*(M. R. BOYER)
D. PALFREYMAN
A. R. SMALL
*(G. W. BOOTH)
J. L. SPENCE
H. G. TASKER
G. H. WORRALL

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* Alternate.

CONSTITUTION AND BY-LAWS
OF THE
SOCIETY OF MOTION PICTURE ENGINEERS*

CONSTITUTION

Article I

Name

The name of this association shall be SOCIETY OF MOTION PICTURE ENGINEERS.

Article II

Object

Its objects shall be: Advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the equipment, mechanisms, and practices employed therein, the maintenance of a high professional standing among its members, and the dissemination of scientific knowledge by publication.

Article III

Eligibility

Any person of good character may be a member in any grade for which he is eligible.

Article IV

Officers

The officers of the Society shall be a President, a Past-President, an Executive Vice-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of the President, the Past-President, the Executive Vice-President, the Engineering Vice-President, the Editorial Vice-President, the Financial Vice-President, and the Convention Vice-President shall be two years, and the Secretary and the Treasurer one year. Of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two shall be elected alternately each year, or until their successors are chosen. The President shall not be immediately eligible to succeed himself in office.

Article V

Board of Governors

The Board of Governors shall consist of the President, the Past-President, the five Vice-Presidents, the Secretary, the Treasurer, the Section Chairmen, and

* Corrected to March 15, 1941.

five elected Governors. Two, and three, of the Governors shall be elected alternately each year to serve for two years.

Article VI

Meetings

There shall be an annual meeting, and such other meetings as stated in the By-Laws.

Article VII

Amendments

This Constitution may be amended as follows: Amendments shall be approved by the Board of Governors, and shall be submitted for discussion at any regular members' meeting. The proposed amendment and complete discussion then shall be submitted to the entire Active, Fellow, and Honorary membership, together with letter ballot as soon as possible after the meeting. Two-thirds of the vote cast within sixty days after mailing shall be required to carry the amendment.

BY-LAWS

By-Law I

Membership

Sec. 1.—The membership of the Society shall consist of Honorary members, Fellows, Active members, Associate members, and Sustaining members.

An **Honorary member** is one who has performed eminent services in the advancement of motion picture engineering or in the allied arts. An Honorary member shall be entitled to vote and to hold any office in the Society.

A **Fellow** is one who shall not be less than thirty years of age and who shall comply with the requirements of either (*a*) or (*b*) for Active members and, in addition, shall by his proficiency and contributions have attained to an outstanding rank among engineers or executives of the motion picture industry. A Fellow shall be entitled to vote and to hold any office in the Society.

An **Active member** is one who shall be not less than 25 years of age, and shall be:

(*a*) A motion picture engineer by profession. He shall have been engaged in the practice of his profession for a period of at least three years, and shall have taken responsibility for the design, installation, or operation of systems or apparatus pertaining to the motion picture industry.

(*b*) A person regularly employed in motion picture or closely allied work, who by his inventions or proficiency in motion picture science or as an executive of a motion picture enterprise of large scope, has attained to a recognized standing in the motion picture industry. In case of such an executive, the applicant must be qualified to take full charge of the broader features of motion picture engineering involved in the work under his direction.

(*c*) An Active member is privileged to vote and to hold any office in the Society.

An **Associate member** is one who shall be not less than 18 years of age, and shall be a person who is interested in or connected with the study of motion picture

technical problems or the application of them. An Associate member is not privileged to vote, to hold office or to act as chairman of any committee, although he may serve upon any committee to which he may be appointed; and, when so appointed, shall be entitled to the full voting privileges of a committee member.

(*d*) A student member is any person registered as a student, graduate or undergraduate, in a college, university, or educational institution, pursuing a course of studies in science or engineering that evidences interest in motion picture technology. Membership in this grade shall not extend more than one year beyond the termination of the student status described above. A student member shall have the same privileges as Associate members of the Society.

A **Sustaining member** is an individual, a firm, or corporation contributing substantially to the financial support of the Society.

Sec. 2.—All applications for membership or transfer, except for honorary or fellow membership, shall be made on blank forms provided for the purpose, and shall give a complete record of the applicant's education and experience. Honorary and Fellow membership may not be applied for.

Sec. 3.—(*a*) An **Honorary** membership may be granted upon recommendation of the Board of Governors when confirmed by a four-fifths majority vote of the Honorary members, Fellows, and Active members present at any regular meeting of the Society. An Honorary member shall be exempt from all dues.

(*b*) Fellow membership may be granted upon recommendation of the Fellow Membership Award Committee, when confirmed by a three-fourths majority vote of the Board of Governors.

(*c*) Applicants for Active Membership shall give as reference at least three members of Active or of higher grade in good standing. Applicants shall be elected to membership by the unanimous approval of the entire membership of the appropriate Admissions Committee. In the event of a single dissenting vote or failure of any member of the Admissions Committee to vote, the application shall be referred to the Board of Governors, in which case approval of at least three-fourths of the Board of Governors shall be required.

(*d*) Applicants for Associate membership shall give as reference at least one member of higher grade in good standing. Applicants shall be elected to membership by approval of a majority of the appropriate Admissions Committee.

(*e*) Applicants for student membership shall give as reference the head of the Department of the Institution he is attending; this faculty member not necessarily being a member of the Society.

By-Law II

Officers

Sec. 1.—An officer or governor shall be an Honorary, a Fellow, or Active member.

Sec. 2.—Vacancies in the Board of Governors shall be filled by the Board of Governors until the annual meeting of the Society.

By-Law III

Board of Governors

Sec. 1.—The Board of Governors shall transact the business of the Society between members' meetings, and shall meet at the call of the president.

Sec. 2.—A majority of the Board of Governors shall constitute a quorum at regular meetings.

Sec. 3.—When voting by letter ballot, a majority affirmative vote of the total membership of the Board of Governors shall carry approval, except as otherwise provided.

Sec. 4.—The Board of Governors, when making nominations to office, and to the Board, shall endeavor to nominate persons, who in the aggregate are representative of the various branches or organizations of the motion picture industry, to the end that there shall be no substantial predominance upon the Board, as the result of its own action, of representatives of any one or more branches or organizations of the industry.

By-Law IV

Committees

Sec. 1.—All committees, except as otherwise specified, shall be appointed by the President.

Sec. 2.—All committees shall be appointed to act for the term served by the officer who shall appoint the committees, unless their appointment is sooner terminated by the appointing officer.

Sec. 3.—Chairman of the committees shall not be eligible to serve in such capacity for more than two consecutive terms.

Sec. 4.—Standing committees of the Society shall be as follows to be appointed as designated:—

(*a*) *Appointed by the President and confirmed by the Board of Governors*

Progress Award Committee
Journal Award Committee
Honorary Membership Committee
Fellow Membership Award Committee
Admissions Committees
(Atlantic and Mid-West Sections)
(Pacific Coast Section)
European Advisory Committee

(*b*) *Appointed by the Engineering Vice-President*

Sound Committee
Standards Committee
Studio Lighting Committee
Color Committee
Theater Engineering Committee
Exchange Practice Committee
Non-Theatrical Equipment Committee
Television Committee
Laboratory Practice Committee
Committee on Cinematography
Process Photography Committee
Committee on Preservation of Film

(*c*) *Appointed by Editorial Vice-President*
Board of Editors
Papers Committee
Progress Committee
Historical Committee
Museum Committee

(*d*) *Appointed by Convention Vice-President*
Publicity Committee
Convention Arrangements Committee
Apparatus Exhibit Committee

(*e*) *Appointed by Financial Vice-President*
Membership and Subscription Committee

Sec. 5.—Two Admissions Committees, one for the Atlantic and Mid-West Sections, and one for the Pacific Coast Section, shall be appointed. The former committee shall consist of a chairman and six Fellow or Active members of the Society of which four shall be members of the Board of Governors. The latter committee shall consist of a Chairman and four Fellow or Active members of the Society including all officers or members of the Board of Governors of the Society residing in the Pacific Coast Section.

By-Law V

Meetings

Sec. 1.—The location of each meeting of the Society shall be determined by the Board of Governors.

Sec. 2.—Only Honorary members, Fellows, and Active members shall be entitled to vote.

Sec. 3.—A quorum of the Society shall consist in number of one-tenth of the total number of Honorary members, Fellows, and Active members as listed in the Society's records at the close of the last fiscal year.

Sec. 4.—The fall convention shall be the annual meeting.

Sec. 5.—Special meetings may be called by the president and upon the request of any three members of the Board of Governors not including the president.

Sec. 6.—All members of the Society in any grade shall have the privilege of discussing technical material presented before the Society or its Sections.

By-Law VI

Duties of Officers

Sec. 1.—The **president** shall preside at all business meetings of the Society and shall perform the duties pertaining to that office. As such he shall be the chief executive of the Society, to whom all other officers shall report.

Sec. 2.—In the absence of the president, the officer next in order as listed in Article 4 of the Constitution shall preside at meetings and perform the duties of the president.

Sec. 3.—The five vice-presidents shall perform the duties separately enumerated below for each office, or as defined by the president:

(*a*) The **executive vice-president** shall represent the president in such geographical areas of the United States as shall be determined by the Board of Gover-

nors, and shall be responsible for the supervision of the general affairs of the Society in such areas, as directed by the president of the Society.

(*b*) The **engineering vice-president** shall appoint all technical committees. He shall be responsible for the general initiation, supervision, and coördination of the work in and among these committees. He may act as chairman of any committee or otherwise be a member ex-officio.

(*c*) The **editorial vice-president** shall be responsible for the publication of the Society's JOURNAL and all other technical publications. He shall pass upon the suitability of the material for publication, and shall cause material suitable for publication to be solicited as may be needed. He shall appoint a papers committee and an editorial committee. He may act as chairman of any committee or otherwise be a member ex-officio.

(*d*) The **financial vice-president** shall be responsible for the financial operations of the Society, and shall conduct them in accordance with budgets approved by the Board of Governors. He shall study the costs of operation and the income possibilities to the end that the greatest service may be rendered to the members of the Society within the available funds. He shall submit proposed budgets to the Board. He shall appoint at his discretion a ways and means committee, a membership committee, a commercial advertising committee, and such other committees within the scope of his work as may be needed. He may act as chairman of any of these committees or otherwise be a member ex-officio.

(*e*) The **convention vice-president** shall be responsible for the national conventions of the society. He shall appoint a convention arrangements committee, an apparatus exhibit committee, and a publicity committee. He may act as chairman of any committee, or otherwise be a member ex-officio.

Sec. 4.—The **secretary** shall keep a record of all meetings; he shall conduct the correspondence relating to his office, and shall have the care and custody of records, and the seal of the Society.

Sec. 5.—The **treasurer** shall have charge of the funds of the Society and disburse them as and when authorized by the financial vice-president. He shall make an annual report, duly audited, to the Society, and a report at such other times as may be requested. He shall be bonded in an amount to be determined by the Board of Governors and his bond filed with the Secretary.

Sec. 6.—Each officer of the Society, upon the expiration of his term of office, shall transmit to his successor a memorandum outlining the duties and policies of his office.

By-Law VII

Elections

Sec. 1.—(*a*) All officers and five governors shall be elected to their respective offices by a majority of ballots cast by the Active, Fellow, and Honorary members in the following manner:

Not less than three months prior to the annual fall convention, the Board of Governors shall nominate for each vacancy several suitable candidates. Nominations shall first be presented by a Nominating Committee appointed by the President, consisting of nine members, including a chairman. The committee shall be made up of two Past-Presidents, three members of the Board of Governors not up for election, and four other Active, Fellow, or Honorary members, not

currently officers or Governors of the Society. Nominations shall be made by three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final unless any nominee is rejected by a three-quarters vote of the Board of Governors present and voting.

The secretary shall then notify these candidates of their nomination. From the list of acceptances, not more than two names for each vacancy shall be selected by the Board of Governors and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the names of any Active, Fellow, or Honorary members other than those suggested by the Board of Governors may be voted for. The balloting shall then take place.

The ballot shall be enclosed in a blank envelope which is enclosed in an outer envelope bearing the secretary's address and a space for the member's name and address. One of these shall be mailed to each Active, Fellow, and Honorary member of the Society, not less than forty days in advance of the annual fall convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the secretary, sign his name and address on the letter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes.

The sealed envelope shall be delivered by the secretary to a committee of tellers appointed by the president at the annual fall convention. This committee shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly elected officers and governors of the general Society shall take office on the January 1st following their election.

(*b*) The first group of vice-presidents, *viz.*, the executive vice-president, engineering vice-president, editorial vice-president, financial vice-president, convention vice-president, and a fifth governor, shall be nominated by the Board of Governors at its first meeting after the ratification of the corresponding provisions of the Constitution; and the membership shall vote on the candidates in accordance with the procedure prescribed in these By-Laws for regular elections of officers so far as these may be applicable.

By-Law VIII

Dues and Indebtedness

Sec. 1.—The annual dues shall be fifteen dollars ($15) for Fellows and Active members, seven dollars and fifty cents ($7.50) for Associate members, and three dollars ($3.00) for Student members, payable on or before January 1st of each year. Current or first year's dues for new members, dating from the notification of acceptance in the Society, shall be prorated on a monthly basis. Five dollars of these dues shall apply for annual subscription to the JOURNAL. No admission fee will be required for any grade of membership.

Sec. 2.—(*a*) Transfer of membership may be made effective at any time by payment of the pro rata dues for the current year.

(*b*) No credit shall be given for annual dues in a membership transfer from a higher to a lower grade, and such transfers shall take place on January 1st of each year.

(*c*) The Board of Governors upon their own initiative and without a transfer application may elect, by the approval of at least three-fourths of the Board, any Associate or Active member for transfer to any higher grade of membership.

Sec. 3.—Annual dues shall be paid in advance. All Honorary members, Fellows, and Active members in good standing, as defined in Section 5, may vote or otherwise participate in the meetings.

Sec. 4.—Members shall be considered delinquent whose annual dues for the year remain unpaid on February 1st. The first notice of delinquency shall be mailed February 1st. The second notice of delinquency shall be mailed, if necessary, on March 1st, and shall include a statement that the member's name will be removed from the mailing list for the JOURNAL and other publications of the Society before the mailing of the April issue of the JOURNAL. Members who are in arrears of dues on June 1st, after two notices of such delinquency have been mailed to their last address of record, shall be notified their names have been removed from the mailing list and shall be warned unless remittance is received on or before August 1st, their names shall be submitted to the Board of Governors for action at the next meeting. Back issues of the JOURNAL shall be sent, if available, to members whose dues have been paid prior to August 1st.

Sec. 5.—(*a*) Members whose dues remain unpaid on October 1st may be dropped from the rolls of the Society by majority vote and action of the Board or the Board may take such action as it sees fit.

(*b*) Anyone who has been dropped from the rolls of the Society for non-payment of dues shall, in the event of his application for reinstatement, be considered as a new member.

(*c*) Any member may be suspended or expelled for cause by a majority vote of the entire Board of Governors; provided he shall be given notice and a copy in writing of the charges preferred against him, and shall be afforded opportunity to be heard ten days prior to such action.

Sec. 6.—The provisions of Sections 1 to 4, inclusive, of this By-Law VIII given above may be modified or rescinded by action of the Board of Governors.

By-Law IX

Emblem

Sec. 1.—The emblem of the Society shall be a facsimile of a four-hole film-reel with the letter S in the upper center opening, and the letters M, P, and E, in the three lower openings, respectively. The Society's emblem may be worn by members only.

By-Law X

Publications

Sec. 1.—Papers read at meetings or submitted at other times, and all material of general interest shall be submitted to the editorial board, and those deemed worthy of permanent record shall be printed in the JOURNAL. A copy of each issue shall be mailed to each member in good standing to his last address of record. Extra copies of the JOURNAL shall be printed for general distribution and may be

obtained from the General Office on payment of a fee fixed by the Board of Governors.

By-Law XI

Local Sections

Sec. 1.—Sections of the Society may be authorized in any state or locality where the Active, Fellow, and Honorary membership exceeds 20. The geographic boundaries of each Section shall be determined by the Board of Governors.

Upon written petition, signed by 20 or more Active members, Fellows and Honorary members, for the authorization of a Section of the Society, the Board of Governors may grant such authorization.

Membership

Sec. 2.—All members of the Society of Motion Picture Engineers in good standing residing in that portion of any country set apart by the Board of Governors tributary to any local Section shall be eligible for membership in that Section, and when so enrolled they shall be entitled to all privileges that such local Section may, under the General Society's Constitution and By-Laws, provide.

Any member of the Society in good standing shall be eligible for non-resident affiliated membership of any Section under conditions and obligations prescribed for the Section. An affiliated member shall receive all notices and publications of the Section but he shall not be entitled to vote at Sectional Meetings.

Sec. 3.—Should the enrolled Active, Fellow, and Honorary membership of a Section fall below 20, or should the technical quality of the presented papers fall below an acceptable level, or the average attendance at meetings not warrant the expense of maintaining the organization, the Board of Governors may cancel its authorization.

Officers

Sec. 4.—The officers of each section shall be a chairman and a secretary-treasurer. The Section chairmen shall automatically become members of the Board of Governors of the General Society, and continue in such positions for the duration of their terms as chairmen of the local sections. Each Section officer shall hold office for one year, or until his successor is chosen.

Board of Managers

Sec. 5.—The Board of Managers shall consist of the Section chairman, the Section past-chairman, the Section secretary-treasurer, and six Active, Fellow, or Honorary members. Each manager of a Section shall hold office for two years, or until his successor is chosen.

Elections

Sec. 6.—The officers and managers of a Section shall be Active, Fellow, or Honorary members of the General Society.

Not less than three months prior to the annual Fall Convention of the Society,

nominations shall be presented to the Board of Managers of the Section by a Nominating Committee appointed by the chairman of the Section, consisting of seven members, including a chairman. The Committee shall be composed of the present chairman, the past-chairman, two other members of the Board of Managers not up for election, and three other Active, Fellow, or Honorary members of the Section not currently officers or managers of the Section. Nominations shall be made by a three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final, unless any nominee is rejected by a three-quarters vote of the Board of Managers, and in the event of such rejection the Board of Managers will make its own nomination.

The Chairman of the Section shall then notify these candidates of their nomination. From the list of acceptances, not more than two names for each vacancy shall be selected by the Board of Managers and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the names of any Active, Fellow, or Honorary members other than those suggested by the Board of Managers may be voted for. The balloting shall then take place.

The ballot shall be enclosed in a blank envelope which is enclosed in an outer envelope bearing the local Secretary-Treasurer's address and a space for the member's name and address. One of these shall be mailed to each Active, Fellow, and Honorary member of the Society, residing in the geographical area covered by the Section, not less than forty days in advance of the annual Fall Convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary-Treasurer, sign his name and address on the letter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes.

The sealed envelopes shall be delivered by the Secretary-Treasurer to his Board of Managers at a duly called meeting. The Board of Managers shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly elected officers and managers shall take office on the January 1st following their election.

Business

Sec. 7.—The business of a Section shall be conducted by the Board of Managers.

Expenses

Sec. 8.—(*a*) As early as possible in the fiscal year, the secretary of each Section shall submit to the Board of Governors of the Society a budget of expenses for the year.

(*b*) The treasurer of the General Society may deposit with each Section secretary-treasurer a sum of money, the amount to be fixed by the Board of Governors, for current expenses.

(*c*) The secretary-treasurer of each Section shall send to the treasurer of the General Society, quarterly or on demand, an itemized account of all expenditures incurred during the preceding interval.

(*d*) Expenses other than those enumerated in the budget, as approved by the Board of Governors of the General Society, shall not be payable from the general funds of the Society without express permission from the Board of Governors.

(*e*) A Section Board of Managers shall defray all expenses of the Section not provided for by the Board of Governors, from funds raised locally by donation, or fixed annual dues, or by both.

(*f*) The secretary of the Society shall, unless otherwise arranged, supply to each Section all stationery and printing necessary for the conduct of its business.

Meetings

Sec. 9.—The regular meetings of a Section shall be held in such places and at such hours as the Board of Managers may designate.

The secretary-treasurer of each Section shall forward to the secretary of the General Society, not later than five days after a meeting of a Section, a statement of the attendance and of the business transacted.

Papers

Sec. 10.—Papers shall be approved by the Section's papers committee previously to their being presented before a Section. Manuscripts of papers presented before a Section, together with a report of the discussions and the proceedings of the Section meetings, shall be forwarded promptly by the Section secretary-treasurer to the secretary of the General Society. Such material may, at the discretion of the Board of Editors of the General Society, be printed in the Society's publications.

Constitution and By-Laws

Sec. 11.—Sections shall abide by the Constitution and By-Laws of the Society and conform to the regulations of the Board of Governors. The conduct of Sections shall always be in conformity with the general policy of the Society as fixed by the Board of Governors.

By-Law XII

Amendments

Sec. 1.—These By-Laws may be amended at any regular meeting of the Society by the affirmative vote of two-thirds of the members present at a meeting who are eligible to vote thereon, a quorum being present, either on the recommendation of the Board of Governors or by a recommendation to the Board of Governors signed by any ten members of active or higher grade, provided that the proposed amendment or amendments shall have been published in the JOURNAL of the Society, in the issue next preceding the date of the stated business meeting of the Society at which the amendment or amendments are to be acted upon.

Sec. 2.—In the event that no quorum of the voting members is present at the time of the meeting referred to in Section 1, the amendment or amendments shall be referred for action to the Board of Governors. The proposed amendment or amendments then become a part of the By-Laws upon receiving the affirmative vote of three-quarters of the Board of Governors.

FIFTY-FIRST SEMI-ANNUAL CONVENTION

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

HOLLYWOOD-ROOSEVELT HOTEL
HOLLYWOOD, CALIF.
MAY 4th–8th, INCLUSIVE

OFFICERS AND COMMITTEES IN CHARGE

EMERY HUSE, *President*
E. A. WILLIFORD, *Past-President*
H. GRIFFIN, *Executive Vice-President*
W. C. KUNZMANN, *Convention Vice-President*
A. C. DOWNES, *Editorial Vice-President*
J. G. FRAYNE, *Chairman, Pacific Coast Section*
C. W. HANDLEY, *Chairman, Local Arrangements Committee*
S. HARRIS, *Chairman, Papers Committee*

Pacific Coast Papers Committee

R. R. SCOVILLE, *Chairman*

G. A. CHAMBERS
C. R. DAILY
F. L. EICH
W. W. LINDSAY, JR.
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W. V. WOLFE

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TENTATIVE PROGRAM

MONDAY, MAY 4, 1942

9:00 a.m. *Hotel Lobby;* **Registration**
12:30 p.m. *Terrace Room;* **Informal Get-Together Luncheon**
Addresses by prominent Hollywood members of the motion picture industry; names to be announced later
2:00 *Blossom Room;* **General Session**
8:00 *Blossom Room;* **Technical Session**

TUESDAY, MAY 5, 1942

9:30 a.m. *Hotel Lobby;* **Registration**
This morning will be left open for a possible trip or other activity to be announced later
2:00 p.m. *Blossom Room;* **Technical Session**
8:00 *Blossom Room;* **Technical Session**

WEDNESDAY, MAY 6, 1942

9:30 a.m. *Hotel Lobby;* **Registration**
10:00 *Blossom Room;* **Technical Session**
2:00 p.m. The afternoon will be left open for a possible trip, to be announced later, or for recreation
8:30 *Blossom Room;* **Fifty-First Semi-Annual Banquet and Dance;** details to be announced later

THURSDAY, MAY 7, 1942

10:30 a.m. *Hotel Lobby;* **Registration**
Open morning
2:00 p.m. *Blossom Room;* **Technical Session**
8:00 *Blossom Room;* **Technical Session**

FRIDAY, MAY 8, 1942

10:00 a.m. *Blossom Room;* **Technical Session**
2:00 p.m. *Blossom Room;* **Technical Session**
8:00 *Blossom Room;* **Technical Session**

Adjournment of the Convention

HEADQUARTERS

The Convention headquarters will be at the Hollywood-Roosevelt Hotel. Excellent accommodations have been assured by the hotel management at the following *per diem* rates:

One person, room and bath	$3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, one person	8.00–14.00
Parlor suite and bath, two persons	12.00–16.00

Room reservation cards will be mailed to the membership early in April and should be returned to the hotel immediately to be assured of satisfactory accommodations.

Indoor and outdoor parking facilities adjacent to the hotel will be available for those who motor to the Convention.

Golfing privileges may be arranged by request of the hotel management or at the registration headquarters.

Registration headquarters will be in the hotel lobby. All members and guests attending the Convention will be expected to register and receive their Convention badges. The registration fees are used to defray the expenses of the Convention, and coöperation in this respect is requested. Identification cards will be supplied, which will serve as admittance to all scheduled or special sessions, studio visits, and trips, and several *de luxe* motion picture theaters on Hollywood Boulevard in the vicinity of the hotel.

Members planning to attend the Convention should consult their local railroad passenger agents regarding train schedules, rates, and stop-over privileges *en route*. For a stop-over at San Francisco the Convention Committee recommends the Mark Hopkins Hotel, on "Nob Hill." Accommodations may be arranged with Mr. George D. Smith, manager of this hotel.

An interesting color-print exhibit will be an adjunct to the Convention and will be open to the public and delegates during the five days of the Convention.

The Convention hostesses promise an interesting program of entertainment for the visiting ladies. A reception parlor will be provided as their headquarters at the hotel.

Note: The Pacific Coast Section officers and managers gave serious consideration to the question of holding the 1942 Spring Convention at Hollywood, and have decided to proceed with arrangements for the meeting. The motion picture industry plays an essential part from the exhibiting and engineering viewpoint in upholding the morale of the general and theater-going public in the present crisis, and accordingly the Convention and Local Arrangements Committees are porceeding with their plans. However, if later deemed advisable in the National interest, the Convention will be subject to cancellation thirty days prior to the announced Convention dates.

W. C. KUNZMANN,
Convention Vice-President

SOCIETY ANNOUNCEMENTS

FIFTY-FIRST SEMI-ANNUAL CONVENTION

HOLLYWOOD-ROOSEVELT HOTEL, HOLLYWOOD, CALIF.
MAY 4th–8th, INCLUSIVE

Plans for the approaching Convention at Hollywood are going forward rapidly and a very fine program of papers will be available. Nine sessions will be devoted to technical presentations, four of them in the evenings to make it possible for those to be present who are engaged at the studios during the daytime.

Details concerning the meetings will be found in another section of this issue of the JOURNAL. The Tentative Program listing the papers and presentations will be mailed to the membership of the Society about the middle of this month, together with hotel reservation cards.

Members who contemplate attending the Convention should not delay in returning their reservation cards, so as to be assured of satisfactory accommodations in the hotel.

ATLANTIC COAST SECTION

On February 19th, at a meeting held at the Hotel Pennsylvania, New York, Messrs. R. Blackinton Fuller and L. S. Rhodes of the Marsh Cinesound, Inc., presented a paper on "Procedural and Dimensional Practices for Production of 16-Mm Motion Pictures for Television Projection." A very interesting and lively discussion followed the presentation.

On March 19th at the New Yorker Hotel, Messrs. A. T. Williams and Wm. A. R. Reedy of the Weston Electric Instrument Corp., Newark, N. J., presented a talk on the "Characteristics, Design, and Use of Photoelectric Exposure Meters." The discussion was divided into two sections, the first covering the characteristics and design of present-day exposure meters, methods of calibrating meters, and the use of reflected rather than incident light as a criterion for exposure.

The second section was devoted to the practical uses of the photoelectric exposure meter, illustrated by slides in both black-and-white and color.

On April 16th, Mr. R. M. Evans of the Eastman Kodak Co., Rochester, N. Y., will present a paper on the present-day status of still-color photography, including Kodacolor, Minicolor, Kotavachrome, 35-mm Kodachrome, and Professional Cut Sheet. The place of the meeting will be announced shortly.

PACIFIC COAST SECTION

At a meeting held on March 10th on the new scoring stage of the RCA Manufacturing Co., at Hollywood, Mr. M. Rettinger, RCA Acoustical Engineer, pre-

sented a paper describing the changes made in the acoustical treatment of the stage for improved sound recording. Following this presentation, Mr. Olin Dupy of the Sound Department of Metro-Goldwyn-Mayer Studios discussed the use of mercury lamps in printers at the M-G-M Laboratory. The meeting closed with a presentation by Mr. Alston Rodgers of the Lamp Department of General Electric Company on "New Light-Sources in the Studios." His presentation was accompanied by a demonstration of the various light-sources.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, the following applicants for membership were admitted into the Society in the Associate grade:

BAUM, WM. J.
War Dept. Theater No. 4
East Garrison,
Camp Roberts, Calif.

BREUNING, F.
5837 Camerford Ave.,
Hollywood, Calif.

BUNCHEZ, S.
130 West 46th St.,
New York, N. Y.

FARLEY, W. L., JR.
Eastman Kodak Company,
6706 Santa Monica Blvd.,
Hollywood, Calif.

JACOBSEN, CARL
4213 Beeman Ave.,
North Hollywood, Calif.

KALHUST, G. F.
605 West Galena St.,
Butte, Montana

KELSYE, R. M.
Motion Picture Section,
Engineer Board,
Fort Belvoir, Va.

MAAG, G. A.
609 West 115th St.,
New York, N. Y.

MCCULLOCH, J. S., JR.
36 Beaver St.,
Sewickley, Pa.

PERRY, B. F.
National Film Board,
Ottawa, Canada

SMART, K. R.
National Carbon Co., Inc.,
808 Olive St.,
St. Louis, Mo.

TRANSUE, WARREN
6387 Ivarene Ave.,
Hollywood, Calif.

WARD, A. A.
10459 Kinnaid Ave.,
Los Angeles, Calif.

YOUNG, R. P.
1214 Central St.,
Evanston, Ill.

In addition, the following applicants have been admitted to the Active grade:

ANDREAS, J. M.
120 North Madison Ave.,
Pasadena, Calif.

COBB, L. L.
334 Huntley Drive,
Los Angeles, Calif.

SIMMONS, N. L., JR.
Eastman Kodak Co.,
6706 Santa Monica Blvd.,
Hollywood, Calif.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

VOLUME XXXVIII • • • MAY, 1942

CONTENTS

Recommended Practices of the Society of Motion Picture Engineers 403

The Quarter-Wave Method of Speaker Testing
S. L. Reiches 457

Sound in Motion Pictures N. Levinson 468

Current Literature 483

Fifty-first Semi-Annual Convention, Hollywood—Hollywood, Calif., May 4–8, 1942

General Information 484

Abstracts of Papers 487

(*The Society is not responsible for statements of authors.*)

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RECOMMENDED PRACTICES

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

The following pages contain all the recommended practices of the Society of Motion Picture Engineers now in force. Previous publications of SMPE Standards and Recommended Practices appeared in the May 1930, November 1934, and March 1938 issues of the JOURNAL.

Prior to a year or so ago specifications such as are contained in these pages were known as SMPE "Standards." By action of the Board of Governors the term "Standard" was discontinued, and only "Recommended Practices" are now issued by the Society. This terminology was adopted in order to avoid confusion with the standards approved by the American Standards Association. SMPE Recommended Practices when submitted to the American Standards Association through the Sectional Committee on Motion Pictures (*Z-22*) may become, when approved by the ASA, either American Standards or American Recommended Practices.

The last publication of American Standards and American Recommended Practices appeared in the March 1941 issue of the JOURNAL. Not all SMPE Recommended Practices have been submitted to or approved by the ASA. In the following pages, those SMPE Recommended Practices that have been approved by the ASA bear the ASA *Z*-number in the upper left-hand corner of the page. The SMPE designation is given in the upper right-hand corner of each page. This designation includes a serial number and the year of adoption by the SMPE. Following the practice of the ASA, the serial numbers will run in consecutive order and will never be used twice. That is, if, for example, the Recommended Practice *SMPE-12-1936* should be revised, the specification will be given a new number, such as *SMPE-48-1943;* if it should be rescinded, the number will merely be dropped.

As this collection of SMPE Recommended Practices has been brought up to date, it may be understood that any specifications that appeared in previous issues of SMPE "Standards" have been superseded, rescinded, or revised to one of the specifications on the following pages.

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Reports of the Standards Committee

(*All references to J. Soc. Mot. Pict. Eng.*)

XV. (Aug., 1930), p. 160
Safety Code for Projection; Wide-Film Dimensions.

XV. (Dec., 1930), p. 818.
Projector and Camera Speeds; Standard Release Print; Screen Brightness; Negative Notching; Wide-Film Dimensions.

XVII. (Sept., 1931), p. 431.
Wide-Film Dimensions.

XVII. (Nov., 1931), p. 819.
Glossary of Technical Terms Used in the Motion Picture Industry.

XIX. (Nov., 1932), p. 477.
16-Mm Standards.

XX. (June, 1933), p. 505.

XXII. (Jan., 1934), p. 17.
Standard SMPE Film Perforation; Unit of Photographic Intensity.
Principle of Intermittency in Sensitometric Measurements.

XXIII. (Nov., 1934), p. 247.
Standards Adopted by the SMPE.

XXIV. (Jan., 1935), p. 16.
Stresa (Italy) Conference on 16-Mm Standards.

XXV. (July, 1935), p. 97.
Report on Reichsfilmkammer at Berlin, April 25, 1935.

XXV. (Aug., 1935), p. 192.

XXV. (Oct., 1935), p. 370.
International Standards Association Questionnaire Regarding 16-Mm Sound-Film Standards.

XXVI. (Jan., 1936), p. 18.

XXVI. (May, 1936), p. 597.
Great Britain Adopts SMPE 16-Mm Standards.

XXVIII. (Jan., 1937), p. 21.

XXVIII. (June, 1937), p. 585.
16-Mm Reduction Printing.

XXIX. (Oct., 1937), p. 376.
Report on Perforation Standards.

XXX. (Mar., 1938), p. 248.
Revision of SMPE Standards Proposed for Adoption by the Society.

XXX. (Mar., 1938), p. 292.
Projection Sprockets, Projection Reels, Sound Records and Scanned Area (35-Mm), Perforations.

XXXI. (July, 1938), p. 65.

XXXI. (Dec., 1938), p. 619.
Cores for 35-Mm and 16-Mm Film, Sound-Track Dimensions, 16-Mm Sound-Film Sprockets, Safety Film.

XXXIV. (Jan., 1940), p. 88.
Sound-Track Dimensions, Safety Film, 16-Mm Raw-Stock Cores.

XXXV. (Nov., 1940), p. 525.
Lantern-Slide Dimensions, Screen Brightness, Release-Print Sound-Track Specifications.

XXXV. (Dec., 1940), p. 566.

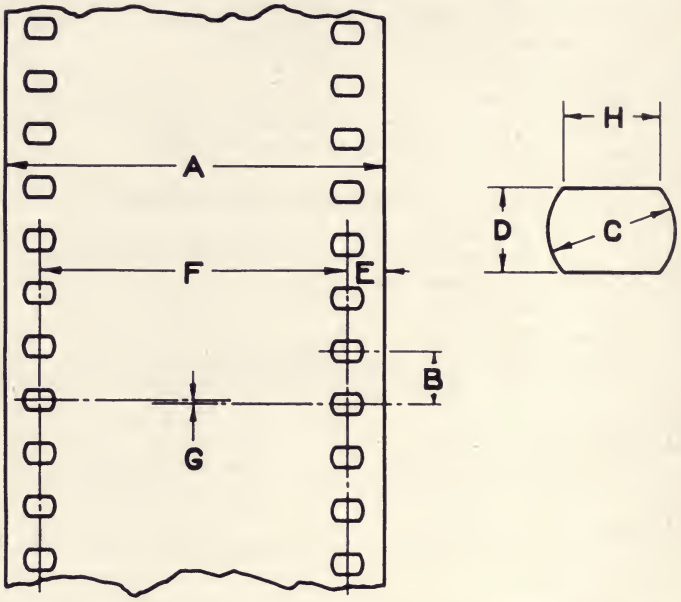
XXXVI. (Mar., 1941), p. 260.
Raw-Stock Cores, Screen Brightness, Lantern-Slides, Raw-Stock Cutting and Perforating Specifications, Screen Brightness.

XXXVII. (July, 1941), p. 76.

XXXVII. (Nov., 1941), p. 535.
Direction of Winding 16-Mm Film, Edge-Numbering 16-Mm Film.

XXXVIII. (Jan., 1942), p. 87.
Direction of Winding 16-Mm Film, Edge-Numbering 16-Mm Film.

Same as‡ ASA Z22.1 1930	SMPE RECOMMENDED PRACTICE For 35-mm Motion Picture Film CUTTING AND PERFORATING NEGATIVE RAW STOCK*	SMPE-1 1941



	Millimeters	*Inch Equivalents*
A	35.00 + 0.00 − 0.05	1.378 + 0.000 − 0.002
B	4.75 ± 0.013	0.1870 ± 0.0005
*C***	2.794 ± 0.01	0.1100 ± 0.0004
D	1.85 ± 0.01	0.0730 ± 0.0004
E	3.40 ± 0.05	0.134 ± 0.002
F	28.17 ± 0.05	1.109 ± 0.002
G	Not > 0.025	Not > 0.001
H	2.08 ± 0.025	0.082 ± 0.001
L†	475.00 ± 0.38	18.70 ± 0.015

** Diameter of circle of curvature.
† *L* = length of any 100 consecutive perforation intervals.

* For picture negative and certain special processes.

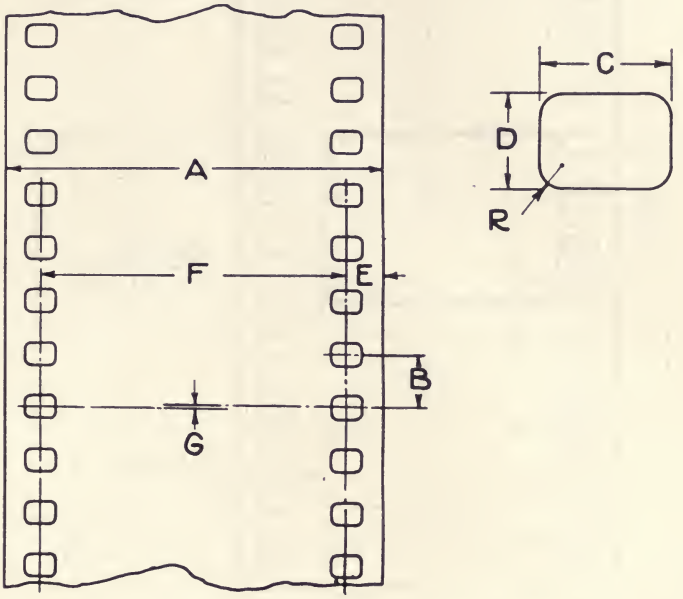
These dimensions and tolerances apply to the material immediately after cutting and perforating.

‡ Except that Z22.1—1930 (see *J. Soc. Mot. Pic. Eng.*, March, 1938, p. 261) was specified for both negative and positive raw stock.

SMPE RECOMMENDED PRACTICE
For 35-mm Motion Picture Film

CUTTING AND PERFORATING POSITIVE RAW STOCK*

SMPE-2
1941



	Millimeters	*Inch Equivalents*
A	35.00 + 0.00 − 0.05	1.378 + 0.000 − 0.002
B	4.750 ± 0.013	0.1870 ± 0.0005
C	2.794 ± 0.01	0.1100 ± 0.0004
D	1.98 ± 0.01	0.0780 ± 0.0004
E	3.40 ± 0.05	0.134 ± 0.002
F	28.17 ± 0.05	1.109 ± 0.002
G	Not > 0.025	Not > 0.001
*L***	475.00 ± 0.38	18.70 ± 0.015
R	0.5	0.020

** *L* = length of any 100 consecutive perforation intervals.

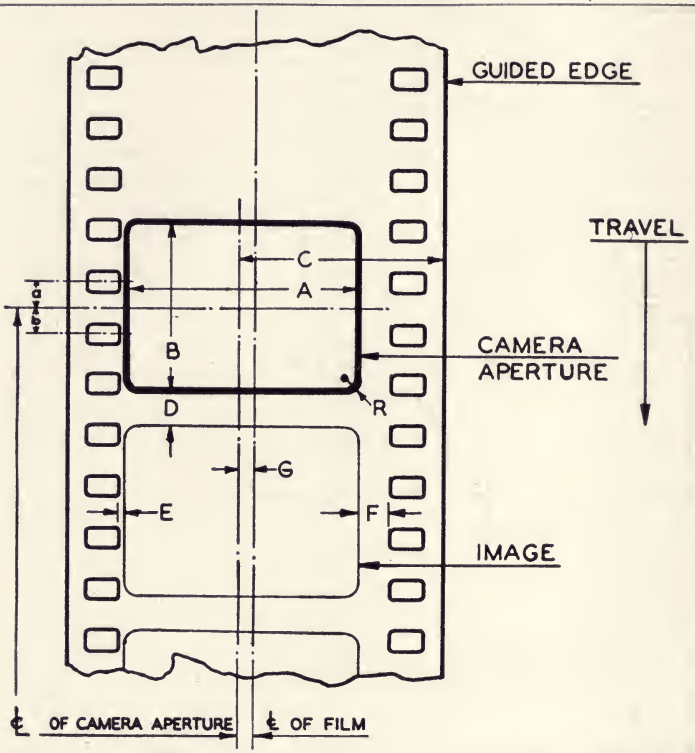
* For positive prints and sound recording.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

SMPE RECOMMENDED PRACTICE
For 35-mm Motion Picture Sound-Film

CAMERA APERTURE

SMPE-3
1936



	Millimeters	*Inch Equivalents*
A	22.05 ± 0.05	0.868 ± 0.002
B	16.03 ± 0.05	0.631 ± 0.002
C	18.90 ± 0.05	0.744 ± 0.002
D	2.97	0.117
E	0.25	0.010
F	3.07	0.121
G	1.40	0.055
R	0.8 approx.	0.03 approx.

$a = b = 1/2$ longitudinal perforation pitch.

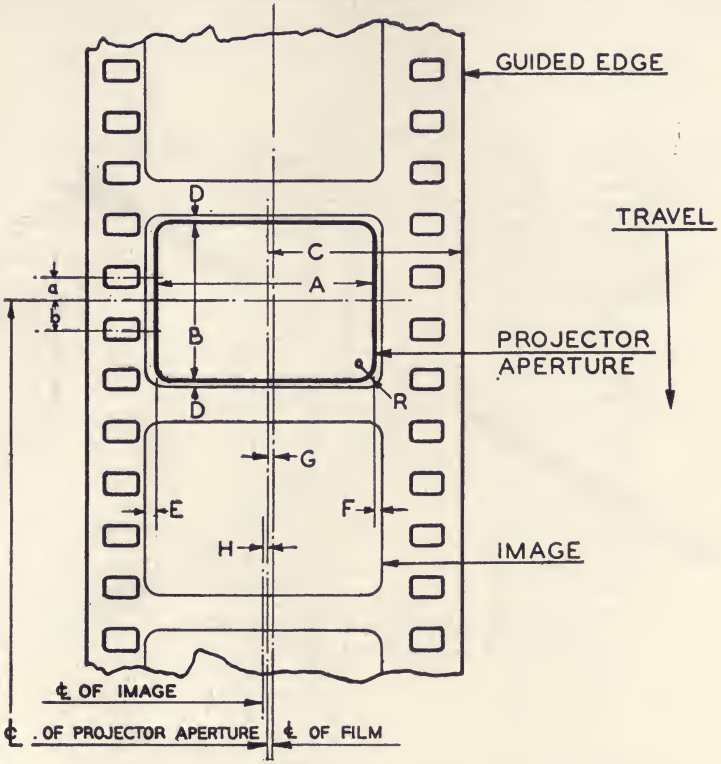
The aperture dimensions given, in combination with the projector aperture shown in *DS-35-4-1*, result in a screen picture having a height-to-width ratio of 3 × 4 when the projection angle is 14 degrees.

These dimensions and locations are shown relative to unshrunk raw stock.

SMPE RECOMMENDED PRACTICE
For 35-mm Motion Picture Sound-Film

PROJECTOR APERTURE

SMPE-4
1932



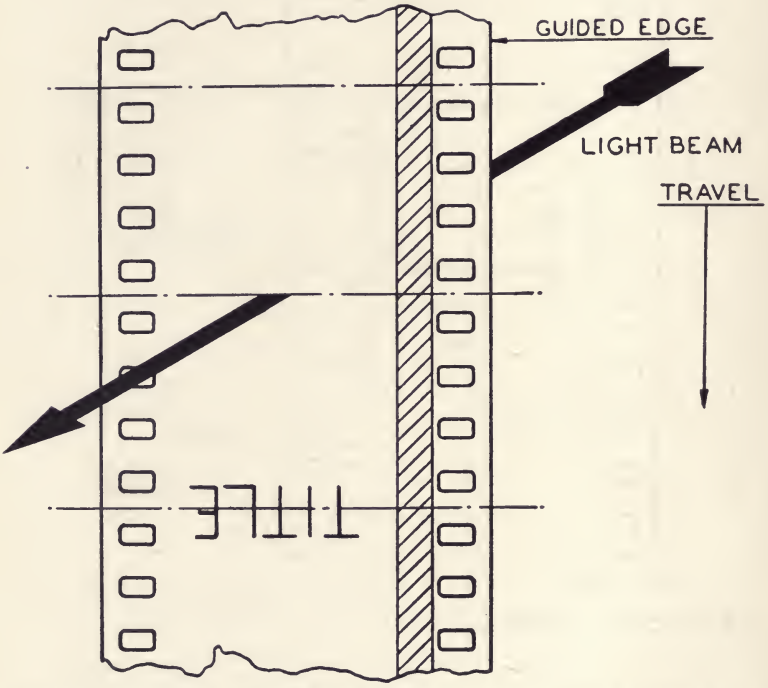
	Millimeters	*Inch Equivalents*
A	20.95 ± 0.05	0.825 ± 0.002
B	15.25 ± 0.05	0.600 ± 0.002
C	18.74 ± 0.05	0.738 ± 0.002
D	0.39	0.015
E	0.71	0.028
F	0.38	0.015
G	1.24	0.049
H	0.15	0.006
R	1.3 approx.	0.05 approx.

$a = b = 1/2$ longitudinal perforation pitch.

The aperture dimensions given result in a screen picture having a height-to-width ratio of 3 × 4 when the projection angle is 14 degrees.

These dimensions and locations are shown relative to unshrunk raw stock.

Same as ASA Z22.2 1941	SMPE RECOMMENDED PRACTICE For 35-mm Motion Picture Sound-Film	SMPE-5 1936
	EMULSION AND SOUND RECORD POSITIONS IN CAMERA—NEGATIVE	



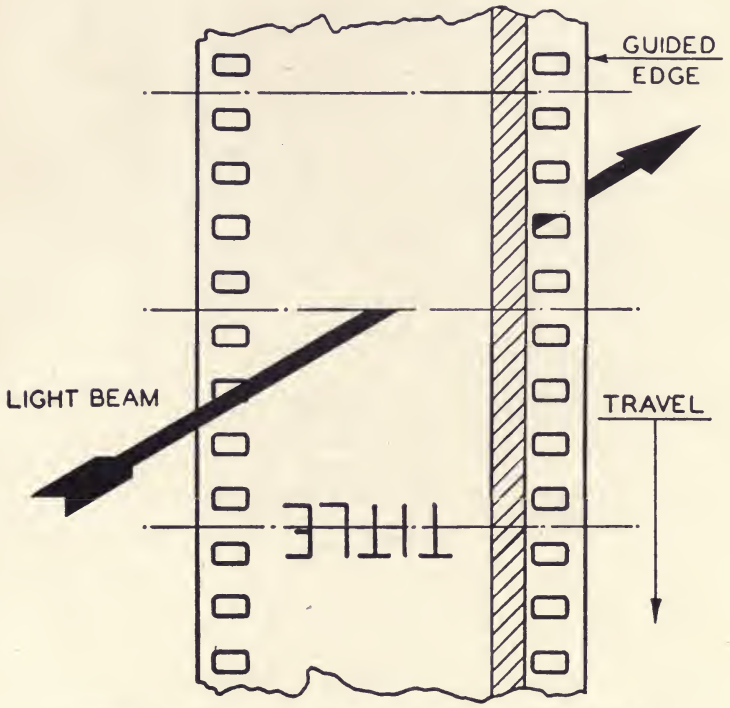
Drawing shows film as seen from inside the camera looking toward the camera lens.

(*1*) Emulsion position in camera: *toward the lens, except for special processes.*

(*2*) Speed: 24 frames per second.

(*3*) Distance between center of picture and corresponding sound: 20 frames.

Same as ASA Z22.3 1941	SMPE RECOMMENDED PRACTICE For 35-mm Motion Picture Sound-Film EMULSION AND SOUND RECORD POSITIONS IN PROJECTOR—POSITIVE For Direct Front Projection	SMPE-6 1936



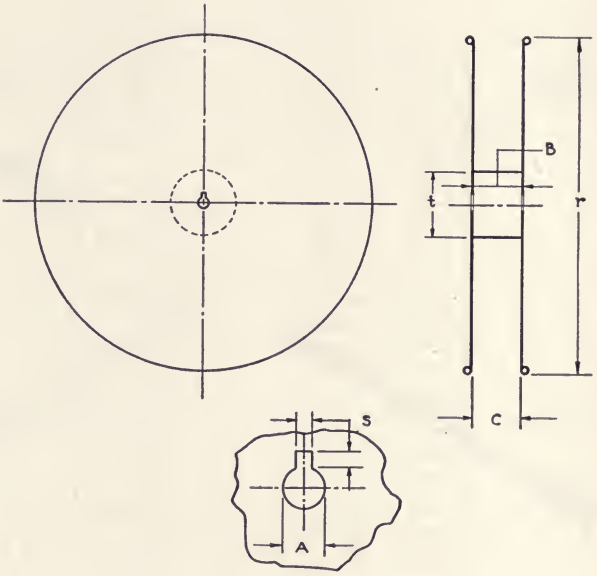
Drawing shows film as seen from the light-source in the projector.

(*1*) Emulsion position in projector: *toward the light-source, except for special processes.*

(*2*) Speed: 24 frames per second.

(*3*) Distance between center of picture and corresponding sound: 20 frames.

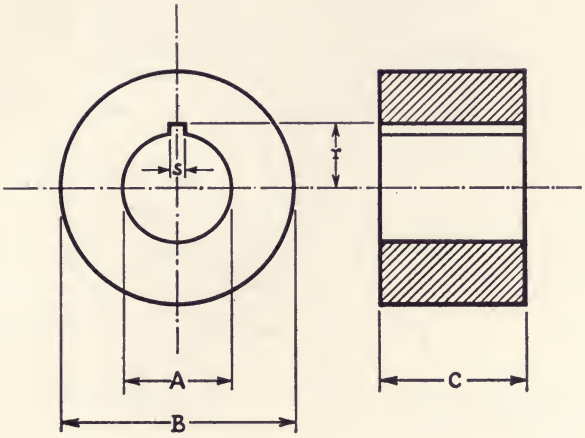
Same as ASA Z22.4 1941	SMPE RECOMMENDED PRACTICE For 35-mm Motion Picture Film PROJECTION REELS	SMPE-7 1938



Capacity	*300 Meters*	*1000 Feet*	*600 Meters*	*2000 Feet*
	Millimeters	*Inch Equivalents*	*Millimeters*	*Inch Equivalents*
A	8.3 Min	0.328 Min	8.3 Min	0.328 Min
*B**	40.1	1.58	40.1	1.58
C	38.1	1.50	38.1	1.50
	Recommended Practice			
r	254.0	10.0	368.0	14.5
s	3.17	0.125	3.17	0.125
t	50.8	2.0	101.6	4.0

* This dimension applies only within a radius of 0.5 inch from the axis of the reel.

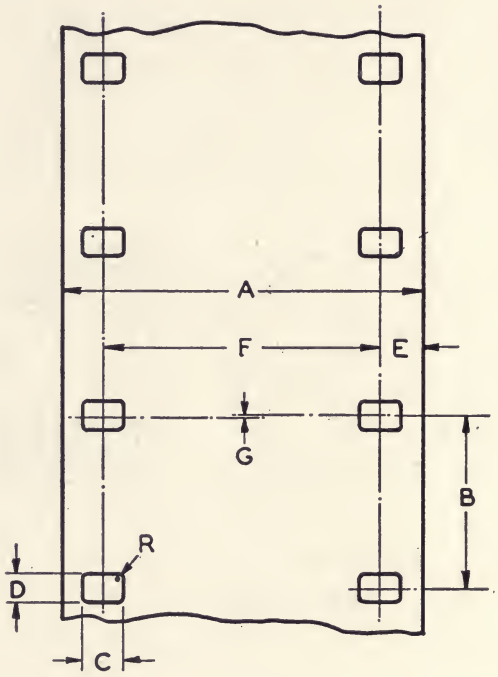
	SMPE RECOMMENDED PRACTICE For 35-mm Motion Picture Film RAW-STOCK CORES	SMPE-8 1941



	Millimeters	*Inch Equivalents*
A	25.90 ± 0.20	1.020 ± 0.008
B	50.00 ± 0.25	1.968 ± 0.010
C	34.50 ± 0.50	1.358 ± 0.020
	Recommended Practice	
r	16.70 ± 0.30	0.657 ± 0.012
s	4.00 ± 0.20	0.157 ± 0.008

Bore *A* to fit freely to hub 25.40 ± 0.1 mm or 1.000 ± 0.004 inch diameter.

Same as ASA Z22.5 1941	SMPE RECOMMENDED PRACTICE For 16-mm Silent Motion Picture Film CUTTING AND PERFORATING NEGATIVE AND POSITIVE RAW STOCK	SMPE-9 1936

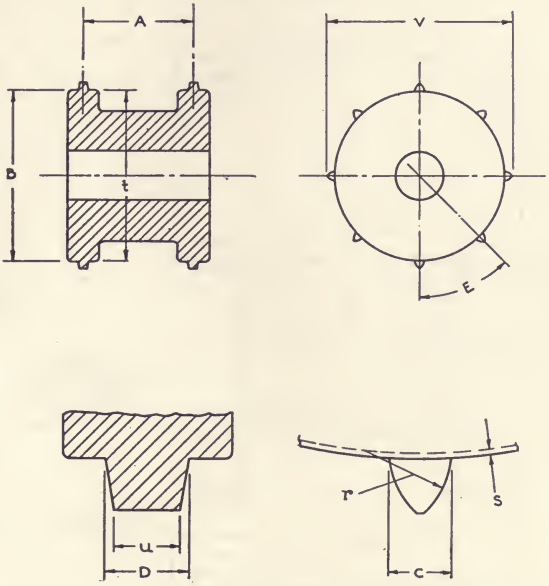


	Millimeters	*Inch Equivalents*
A	16.00 + 0.00 − 0.05	0.630 + 0.000 − 0.002
B	7.620 ± 0.013	0.3000 ± 0.0005
C	1.83 ± 0.01	0.0720 ± 0.0004
D	1.27 ± 0.01	0.0500 ± 0.0004
E	1.83 ± 0.05	0.072 ± 0.002
F	12.320 ± 0.025	0.485 ± 0.001
G	Not > 0.025	Not > 0.001
*L**	762.00 ± 0.76	30.0 ± 0.03
R	0.25	0.010

* L = the length of any 100 consecutive perforation intervals.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

Same as ASA Z22.6 1941	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Film	SMPE-10 1934
	PROJECTOR SPROCKETS	



	N	B		E	Number of Teeth in Mesh: 3 C		4 C		5 C		6 C	
		Mm	In		Mm	In	Mm	In	Mm	In	Mm	In
Feed	6	14.38	0.566	60°0′ ± 0.5′	1.02	0.040						
	8	19.23	0.757	45°0′ ± 0.5′	1.02	0.040	0.91	0.036				
	12	28.93	1.139	30°0′ ± 0.5′	1.02	0.040	0.91	0.036	0.79	0.031	0.69	0.027
	16	38.63	1.521	22°30′ ± 0.5′	1.02	0.040	0.91	0.036	0.79	0.031	0.69	0.027
Take-Up (Holdback)	6	14.15	0.557	60°0′ ± 0.5′	1.02	0.040						
	8	18.92	0.745	45°0′ ± 0.5′	1.02	0.040	0.91	0.036				
	12	28.50	1.122	30°0′ ± 0.5′	1.02	0.040	0.91	0.036	0.79	0.031	0.69	0.027
	16	38.05	1.498	22°30′ ± 0.5′	1.02	0.040	0.91	0.036	0.79	0.031	0.69	0.027
Combination	6	14.30	0.563	60°0′ ± 0.5′	1.09	0.043						
	8	19.13	0.753	45°0′ ± 0.5′	1.09	0.043	1.02	0.040				
	12	28.78	1.133	30°0′ ± 0.5′	1.09	0.043	1.02	0.040	0.94	0.037	0.86	0.034
	16	38.43	1.513	22°30′ ± 0.5′	1.09	0.043	1.02	0.040	0.94	0.037	0.86	0.034

For All Sprockets	Millimeters	Inch Equivalents
A	12.22 + 0.05 − 0.00	0.481 + 0.002 − 0.000
D	1.22 + 0.00 − 0.08	0.048 + 0.000 − 0.003
r	1.27	0.050
s	0.08	0.003
t	B − 0.3, Max	B − 0.01, Max
u	1.00	0.039
v	B + 1.52, Max	B + 0.060, Max.

Notes

N = Number of teeth on sprocket.

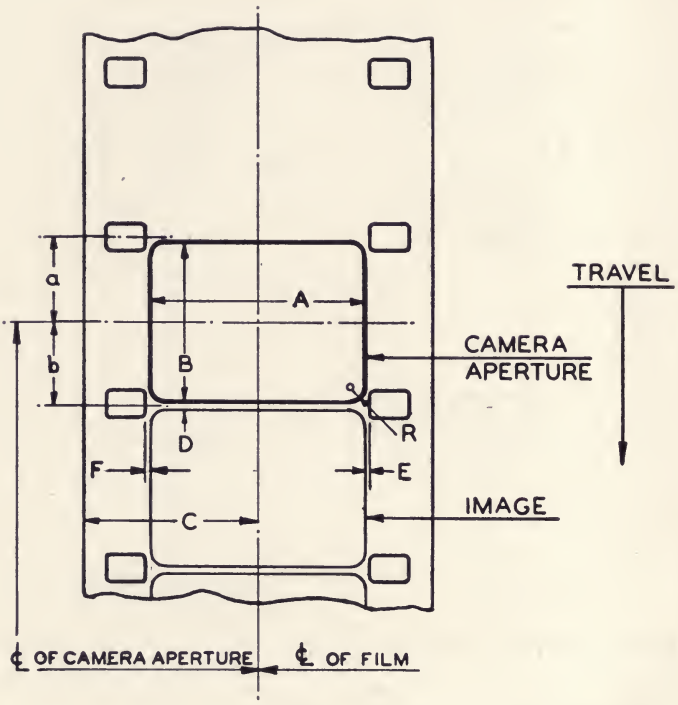
Tolerance for B and C +0.000 to −0.025 mm or +0.000 to −0.001 in.

Dimensional standards indicated by capital letters.

Recommended practice indicated by lower case letters.

Values of C are omitted in cases where the angle of wrap on the sprocket would exceed 180°.

Same as ASA Z22.7 1941	SMPE RECOMMENDED PRACTICE For 16-mm Silent Motion Picture Film	SMPE-11 1936
	CAMERA APERTURE	



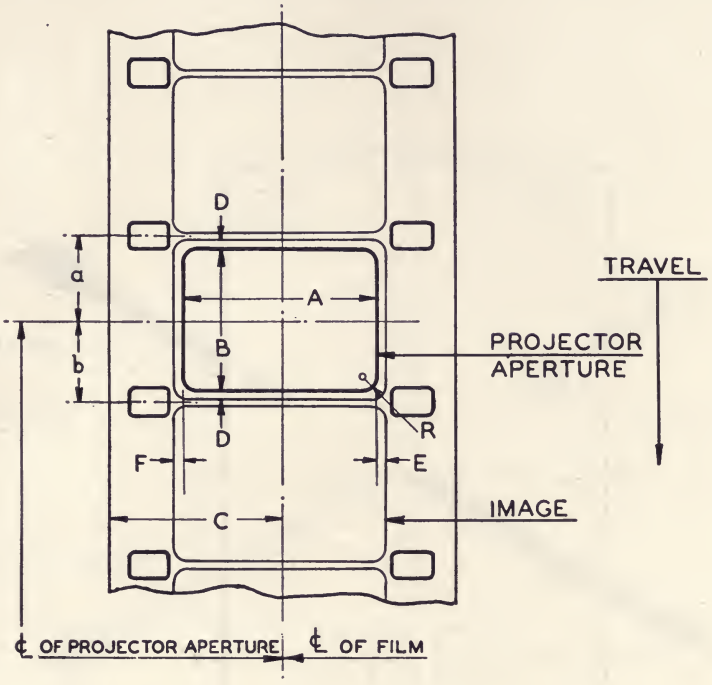
	Millimeters	*Inch Equivalents*
A	10.41 ± 0.05	0.410 ± 0.002
B	7.47 ± 0.05	0.294 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.15	0.006
E	0.05	0.002
F	0.05	0.002
R	0.5 approx.	0.02 approx.

$a = b = {}^1/_2$ longitudinal perforation pitch.

These dimensions and locations are shown relative to unshrunk raw stock.

The center of the frame-line shall pass through the centers of perforations on opposite sides of the film.

Same as ASA Z22.8 1941	SMPE RECOMMENDED PRACTICE For 16-mm Silent Motion Picture Film	SMPE-12 1936
	PROJECTOR APERTURE	

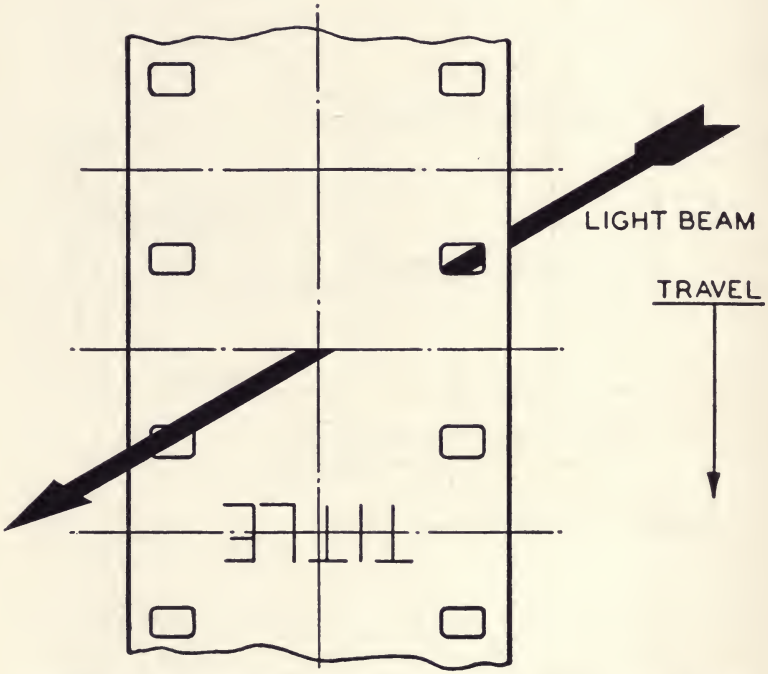


	Millimeters	*Inch Equivalents*
A	9.65 ± 0.05	0.380 ± 0.002
B	7.21 ± 0.05	0.284 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.13	0.005
E	0.38	0.015
F	0.38	0.015
R	0.5 approx.	0.02 approx.
$a = b = 1/2$ longitudinal perforation pitch.		

These dimensions and locations are shown relative to unshrunk raw stock.

The center of the frame-line shall pass through the centers of perforations on opposite sides of the film.

Same as ASA Z22.9 1941	SMPE RECOMMENDED PRACTICE For 16-mm Silent Motion Picture Film	SMPE-13 1936
	EMULSION POSITION IN CAMERA—NEGATIVE	

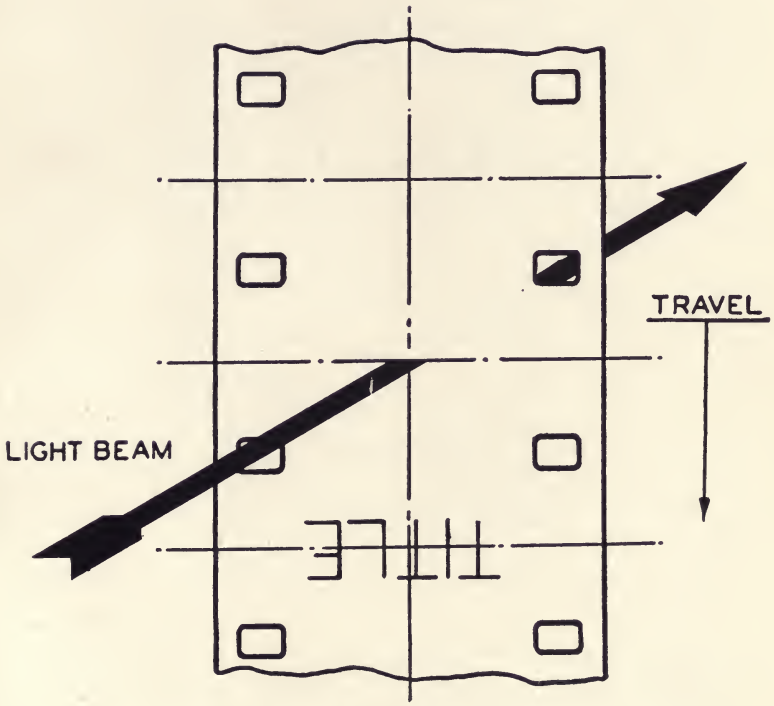


Drawing shows film as seen from inside the camera looking toward the camera lens.

(*1*) Emulsion position in camera: *toward the lens, except for special processes.*

(*2*) Normal speed: 16 frames per second.

Same as ASA Z22.10 1941	SMPE RECOMMENDED PRACTICE For 16-mm Silent Motion Picture Film EMULSION POSITION IN PROJECTOR—POSITIVE For Direct Front Projection	SMPE-14 1936

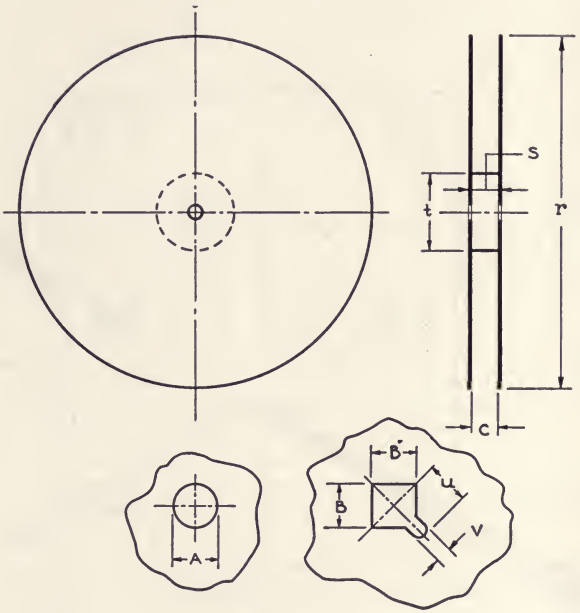


Drawing shows film as seen from the light-source in the projector.

(*1*) Emulsion position in projector: *toward the lens, except for special processes.*

(*2*) Normal speed: 16 frames per second.

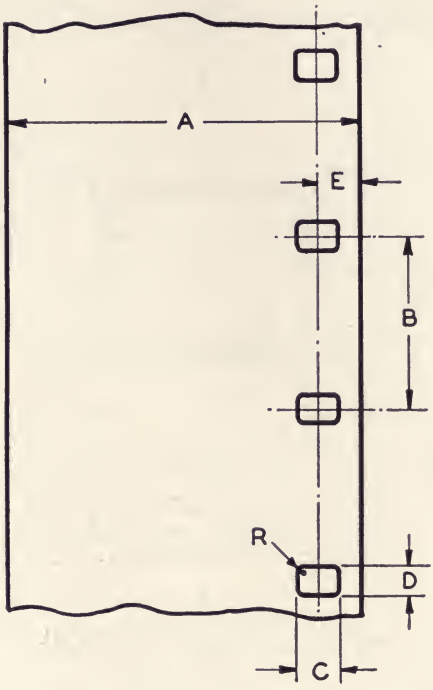
Same as ASA Z22.11 1941	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Film	SMPE-15 1938
	PROJECTION REELS	



	120 Meters	*400 Feet*	*240 Meters*	*800 Feet*	*480 Feet*	*1600 Feet*
	Millimeters	*Inch Equivalents*	*Millimeters*	*Inch Equivalents*	*Millimeters*	*Inch Equivalents*
A	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003
B	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003
C	17.2 Min	0.677 Min	17.2 Min	0.677 Min	17.2 Min	0.677 Min
	Recommended Practice					
r	177.8	7.00	250.8	9.87	355.6	14.00
s	19.23	0.757	19.63	0.773	21.92	0.863
t	37.85	1.490	37.85	1.490	117.48	4.625
u	7.94	0.312	7.94	0.312	7.94	0.312
v	3.17	0.125	3.17	0.125	3.17	0.125

NOTE: Center Spindle Holes. Either a combination of square and round holes or two square holes may be used.

Same as ASA Z22.12 1941	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Sound-Film	SMPE-16 1936
	CUTTING AND PERFORATING NEGATIVE AND POSITIVE RAW STOCK	

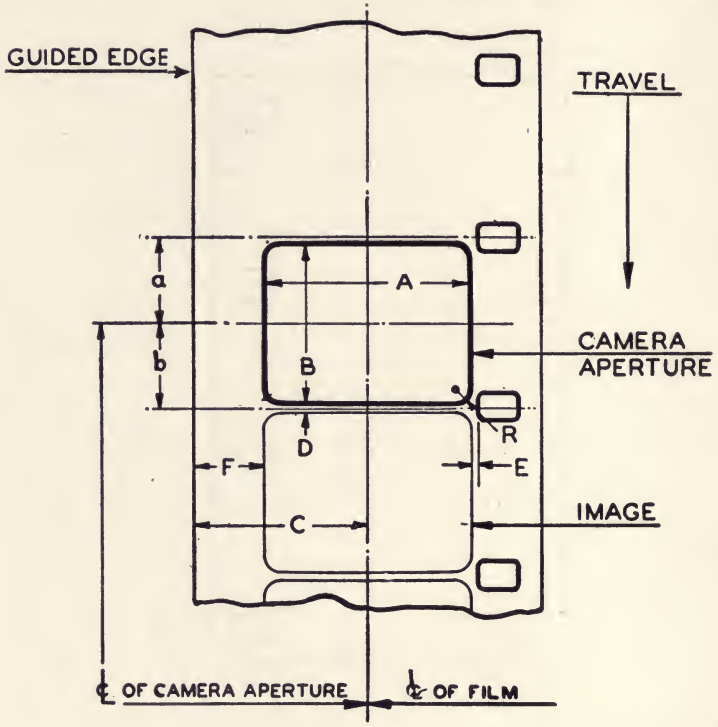


	Millimeters	*Inch Equivalents*
A	16.00 + 0.00 − 0.05	0.630 + 0.000 − 0.002
B	7.620 ± 0.013	0.3000 ± 0.0005
C	1.83 ± 0.01	0.0720 ± 0.0004
D	1.27 ± 0.01	0.0500 ± 0.0004
E	1.83 ± 0.05	0.072 ± 0.002
*L**	762.00 ± 0.76	30.00 ± 0.03
R	0.25	0.010

* L = the length of any 100 consecutive perforation intervals.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

Same as ASA Z22.13 1941	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Sound-Film	SMPE-17 1936
	CAMERA APERTURE	



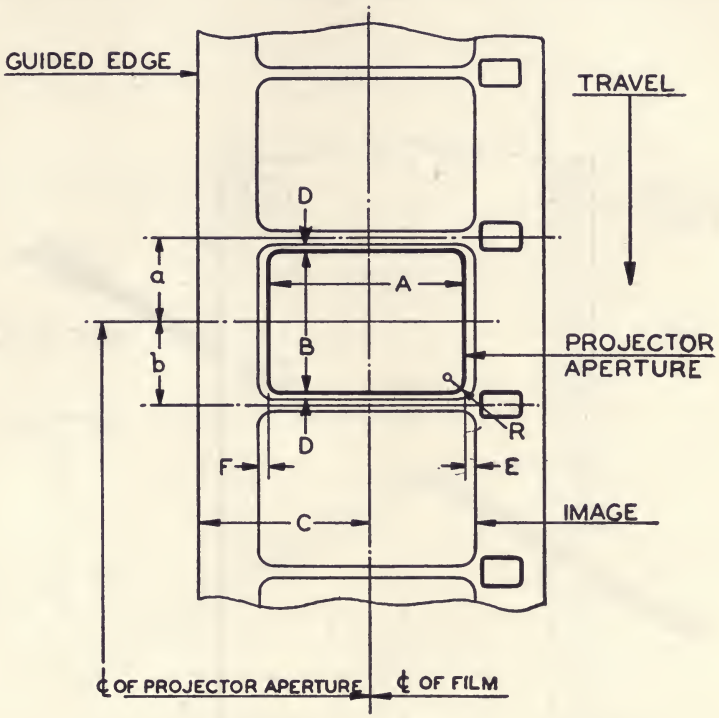
	Millimeters	*Inch Equivalents*
A	10.41 ± 0.05	0.410 ± 0.002
B	7.47 ± 0.05	0.294 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.15	0.006
E	0.05	0.002
F	2.79	0.110
R	0.5 approx.	0.02 approx.

$a = b = {}^1/_2$ longitudinal perforation pitch.

These dimensions and locations are shown relative to unshrunk raw stock.

The center of the frame-line shall pass through the center of a perforation.

Same as ASA Z22.14 1941	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Sound-Film	SMPE-18 1936
	PROJECTOR APERTURE	

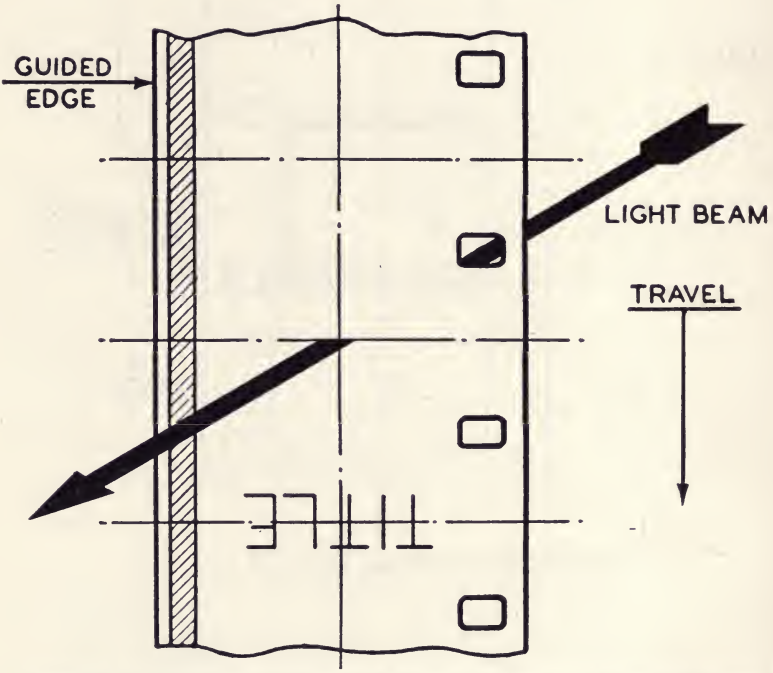


	Millimeters	*Inch Equivalents*
A	9.65 ± 0.05	0.380 ± 0.002
B	7.21 ± 0.05	0.284 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.13	0.005
E	0.38	0.015
F	0.38	0.015
R	0.5 approx.	0.02 approx.
$a = b = 1/2$ longitudinal perforation pitch.		

These dimensions and locations are shown relative to unshrunk raw stock.

The center of the frame-line shall pass through the center of a perforation.

Same as ASA Z22.15 1941	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Sound-Film EMULSION AND SOUND RECORD POSITIONS IN CAMERA—NEGATIVE	SMPE-19 1936



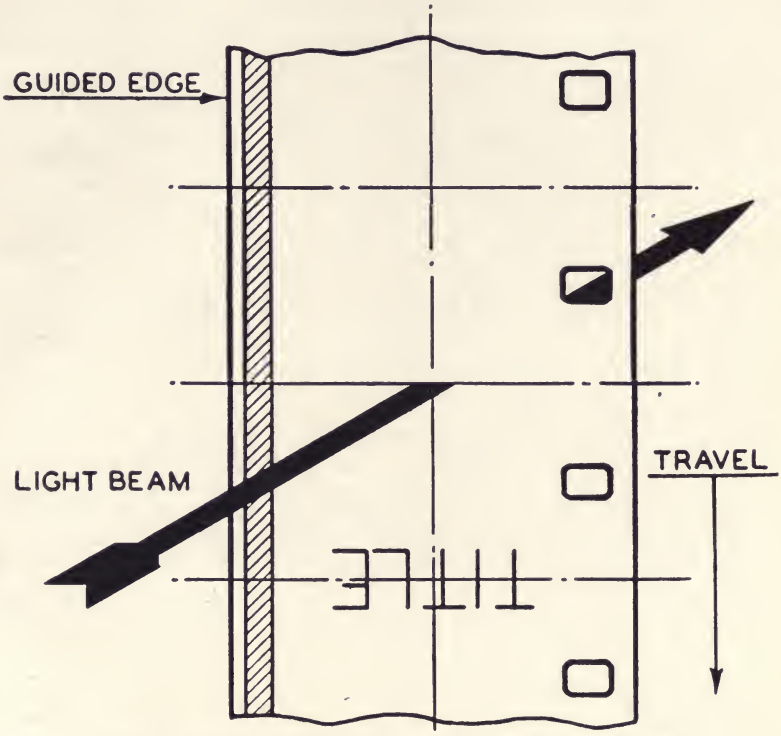
Drawing shows film as seen from inside the camera looking toward the camera lens.

(*1*) Emulsion position in camera: *toward the lens, except for special processes.*

(*2*) Speed: 24 frames per second.

(*3*) Distance between center of picture and corresponding sound: 26 frames.

Same as ASA Z22.16 1941	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Sound-Film EMULSION AND SOUND RECORD POSITIONS IN PROJECTOR—POSITIVE For Direct Front Projection	SMPE-20 1936



Drawing shows film as seen from the light-source in the projector.

(*1*) Emulsion position in projector: *toward the lens, except for special processes.*

(*2*) Speed: 24 frames per second.

(*3*) Distance between center of picture and corresponding sound: 26 frames.

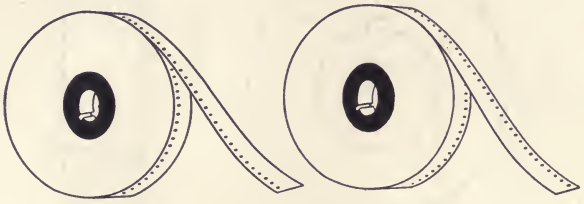
	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Film	SMPE-21 1941
	EDGE-NUMBERING INTERVAL	

If 16-mm film is edge-numbered, the interval between consecutive footage numbers shall be 40 frames.

	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Film	SMPE-22 1941
	DESIGNATION OF DIRECTION OF WINDING OF FILM PERFORATED ALONG ONE EDGE	

When a roll of 16-mm film, perforated along one edge, is held so that the outside end of the film leaves the roll at the top and toward the right, winding *A* shall have the perforations on the edge of the film toward the observer; and winding *B* shall have the perforations on the edge away from the observer. In both cases the emulsion surface shall face inward on the roll.

The following sketch illustrates these definitions:

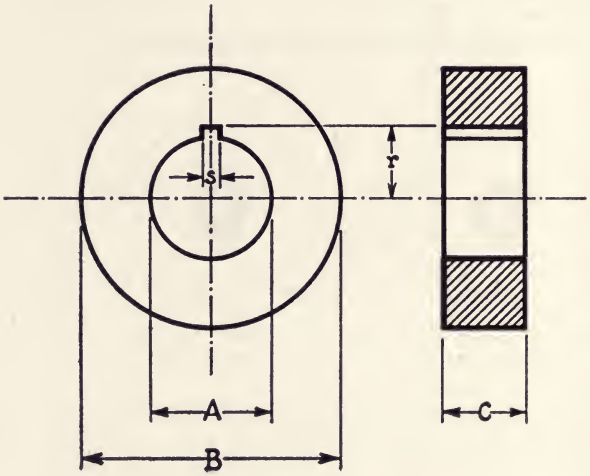


Winding *A*
Emulsion side in

Winding *B*
Emulsion side in

The above-given sketch shows film wound on cores. When the film is wound on a reel having a square hole on one side and a round hole on the other, the square hole shall be understood to be on the side away from the observer.

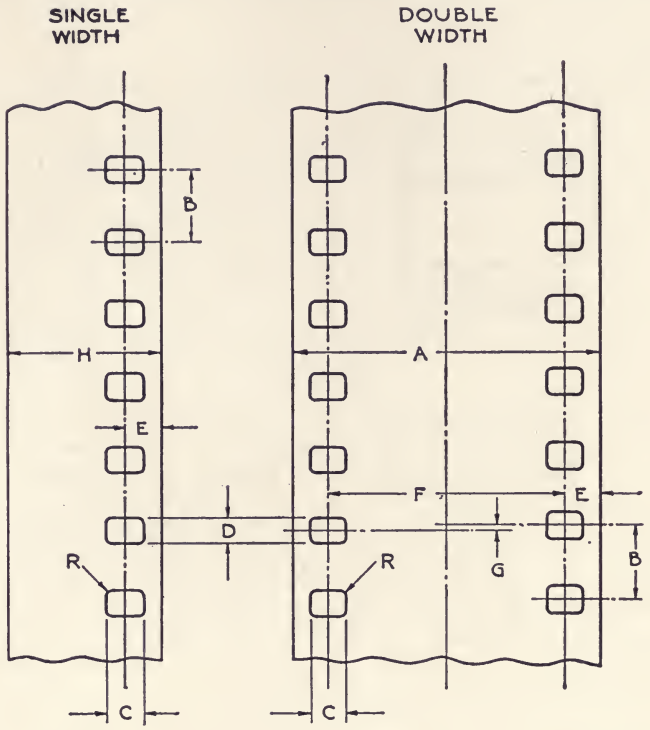
	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Film RAW-STOCK CORES	SMPE-23 1941



	Millimeters	*Inch Equivalents*
A	25.90 ± 0.20	1.020 ± 0.008
B	50.00 ± 0.25	1.968 ± 0.010
C	15.50 ± 0.50	0.610 ± 0.020
	Recommended Practice	
r	16.70 ± 0.30	0.657 ± 0.012
s	4.00 ± 0.20	0.157 ± 0.008

Bore *A* to fit freely to hub 25.40 ± 0.1 mm or 1.000 ± 0.004 inch diameter.

Same as ASA Z22.17 1941	SMPE RECOMMENDED PRACTICE For 8-mm Motion Picture Film CUTTING AND PERFORATING NEGATIVE AND POSITIVE RAW STOCK	SMPE-24 1938



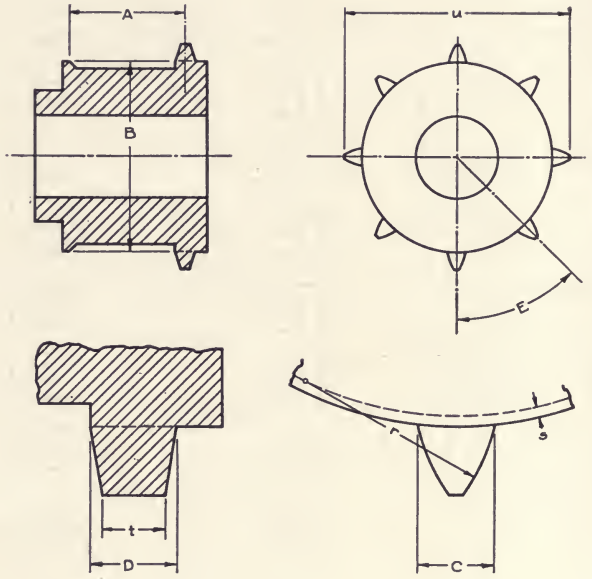
	Millimeters	*Inch Equivalents*
A	16.00 + 0.00 − 0.05	0.630 + 0.000 − 0.002
B	3.810 ± 0.013	0.150 ± 0.0005
C	1.83 ± 0.01	0.072 ± 0.0004
D	1.27 ± 0.01	0.0500 ± 0.0004
E	1.83 ± 0.05	0.072 ± 0.002
F	12.320 ± 0.025	0.485 ± 0.001
G	Not > 0.025	Not > 0.001
H	8.00 + 0.00 − 0.08	0.315 + 0.000 − 0.003
*L**	381.00 ± 0.38	15.000 ± 0.015
R	0.25	0.010

* *L* = the length of any 100 consecutive perforation intervals.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

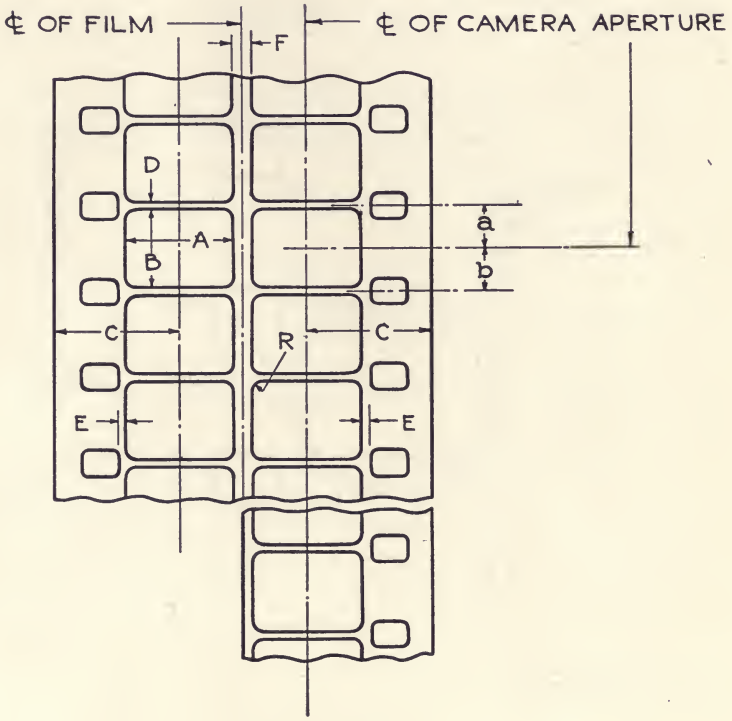
Film may be slit before or after processing.

Same as ASA Z22.18 1941	SMPE RECOMMENDED PRACTICE For 8-mm Motion Picture Film	SMPE-25 1938
	8-TOOTH PROJECTOR SPROCKETS	



	Millimeters	*Inch Equivalents*
A	5.72 ± 0.03	0.225 ± 0.001
B	9.42 + 0.00 − 0.05	0.371 + 0.000 − 0.002
C	1.02 + 0.00 − 0.05	0.040 + 0.000 − 0.002
D	1.14 + 0.08 − 0.00	0.045 + 0.003 − 0.000
E	45°0′ ± 0.5′	
	Recommended Practice	
r	2.54	0.100
s	0.13	0.005
t	0.51	0.020
u	11.33	0.450

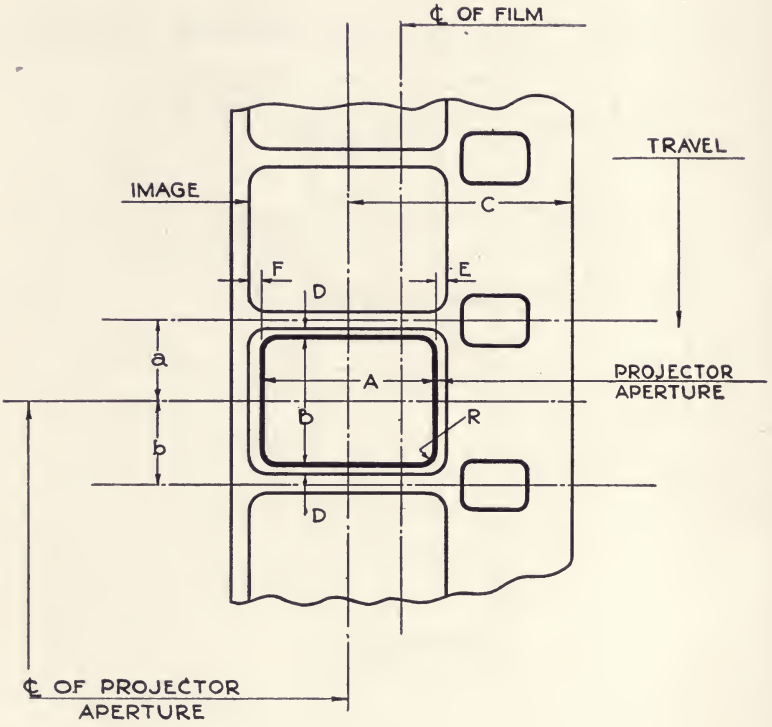
Same as ASA Z22.19 1941	SMPE RECOMMENDED PRACTICE For 8-mm Silent Motion Picture Film CAMERA APERTURE	SMPE-26 1938



	Millimeters	*Inch Equivalents*
A	4.80 ± 0.03	0.189 ± 0.001
B	3.51 ± 0.03	0.138 ± 0.001
C	5.22 ± 0.05	0.205 ± 0.002
D	0.30	0.012
E	0.08	0.003
F	0.76	0.030
R	0.25	0.010

$a = b = {}^1/_2$ longitudinal perforation pitch.

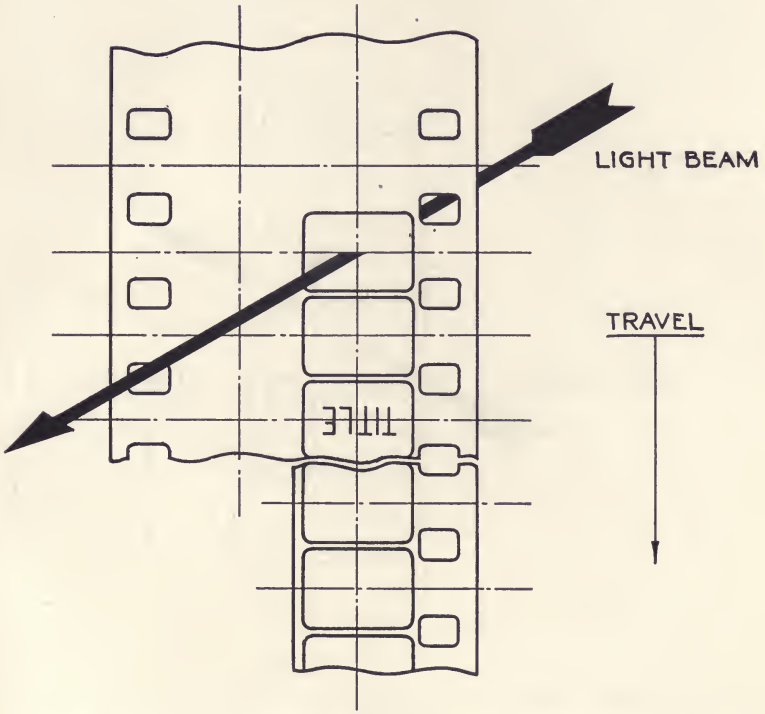
Same as ASA Z22.20 1941	SMPE RECOMMENDED PRACTICE For 8-mm Silent Motion Picture Film	SMPE-27 1938
	PROJECTOR APERTURE	



	Millimeters	*Inch Equivalents*
A	4.37 ± 0.03	0.172 ± 0.001
B	3.28 ± 0.03	0.129 ± 0.001
C	5.22 ± 0.05	0.2055 ± 0.002
D	0.11	0.004
E	0.21	0.008
F	0.21	0.008
R	0.25	0.010

$a = b = {}^1/_2$ longitudinal perforation pitch.

Same as ASA Z22.21 1941	SMPE RECOMMENDED PRACTICE For 8-mm Silent Motion Picture Film	SMPE-28 1938
	EMULSION POSITION IN CAMERA—NEGATIVE	

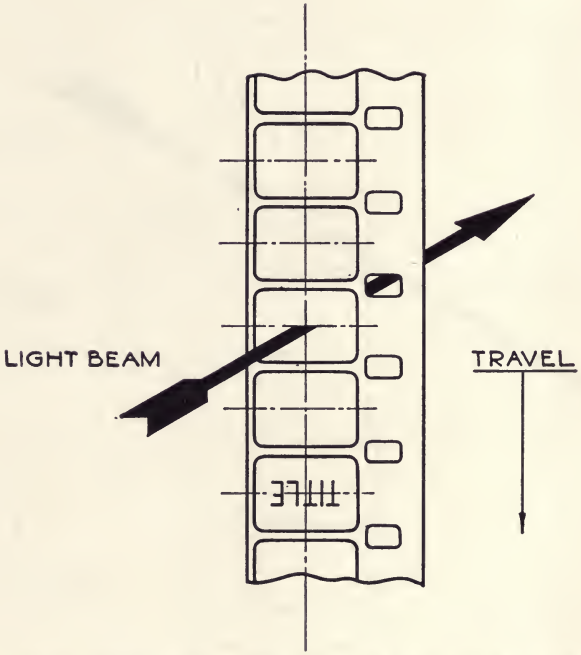


Drawing shows film from inside the camera, looking toward the camera lens.

(*1*) Emulsion position in camera: *toward the lens, except for special processes.*

(*2*) Normal speed: 16 frames per second.

Same as ASA Z22.22 1941	SMPE RECOMMENDED PRACTICE For 8-mm Silent Motion Picture Film EMULSION POSITION IN PROJECTOR—POSITIVE For Direct Front Projection	SMPE-29 1938

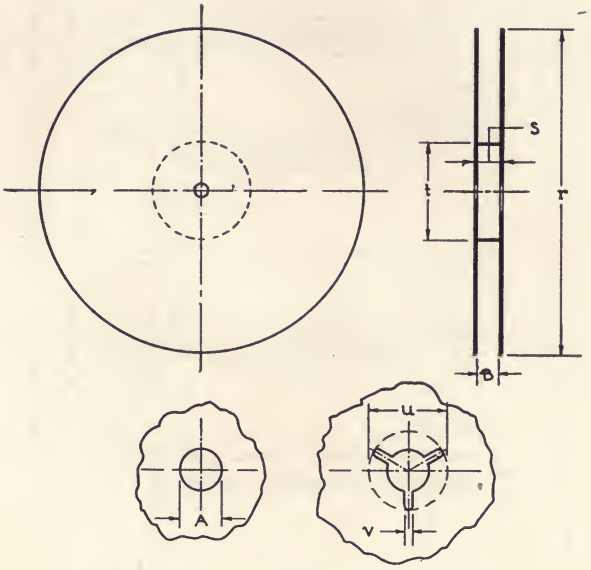


Drawing shows film as seen from the light-source in the projector.

(*1*) Emulsion position in projector: *toward the lens, except for special processes.*

(*2*) Normal speed: 16 frames per second.

Same as ASA Z22.23 1941	SMPE RECOMMENDED PRACTICE For 8-mm Silent Motion Picture Film PROJECTION REELS	SMPE-30 1938



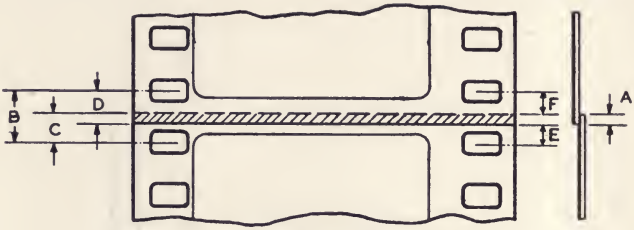
Capacity, 60 M (200 Ft)		
	Millimeters	*Inch Equivalents*
A	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003
B	8.9 Min	0.35 Min
Recommended Practice		
r	127.0	5.00
s	10.5	0.41
t	37.8	1.49
u	16.0	0.63
v	1.6	0.06

Drive side of sprocket may have any desired odd number of driving slots, evenly spaced.

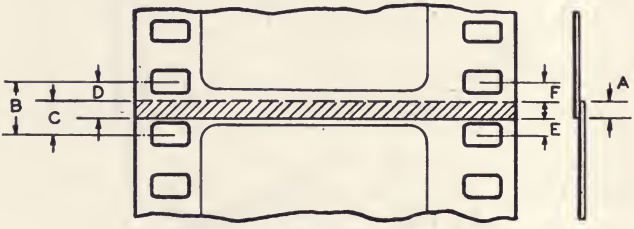
SMPE RECOMMENDED PRACTICE
For 35-mm Motion Picture Sound-Film

FILM SPLICES
NEGATIVE AND POSITIVE

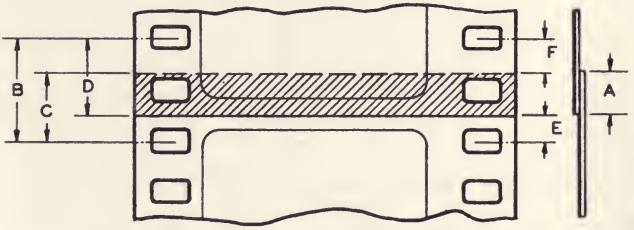
SMPE-31
1936



NEGATIVE SPLICE



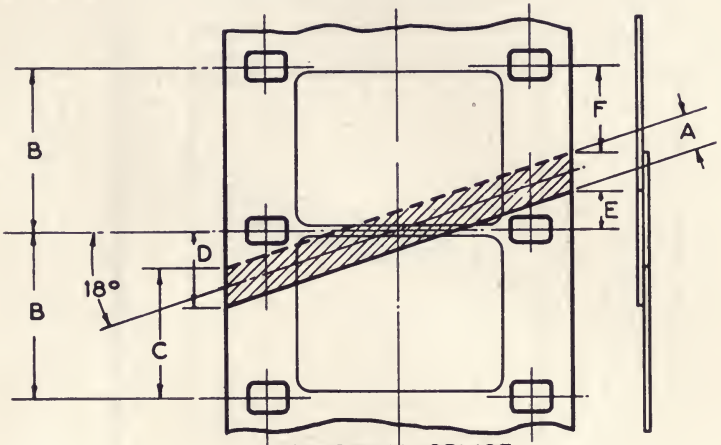
REGULAR POSITIVE SPLICE



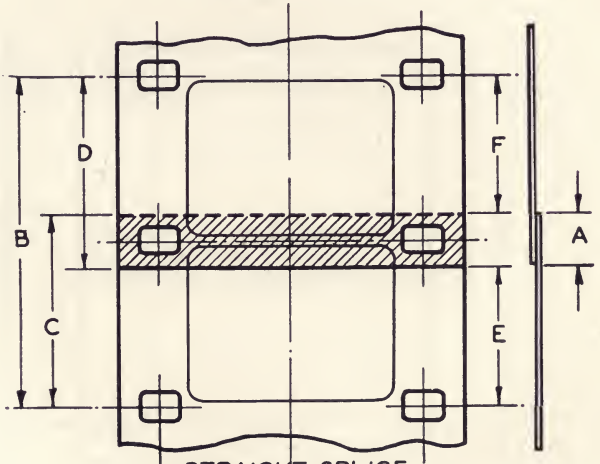
FULL HOLE POSITIVE SPLICE

	Negative		*Regular Positive*		*Full Hole Positive*	
	Mm	*Inch Equiv.*	*Mm*	*Inch Equiv.*	*Mm*	*Inch Equiv.*
A	1.27	0.050	1.83	0.072	3.96	0.156
B	4.75	0.187	4.75	0.187	9.50	0.374
C	3.01	0.119	2.90	0.114	6.35	0.250
D	3.01	0.119	3.68	0.145	7.11	0.280
E	1.74	0.069	1.07	0.042	2.39	0.094
F	1.74	0.069	1.85	0.073	3.15	0.124

Same as ASA Z22.24 1941	SMPE RECOMMENDED PRACTICE For 16-mm Silent Motion Picture Film	SMPE-32 1936
	FILM SPLICES NEGATIVE AND POSITIVE	



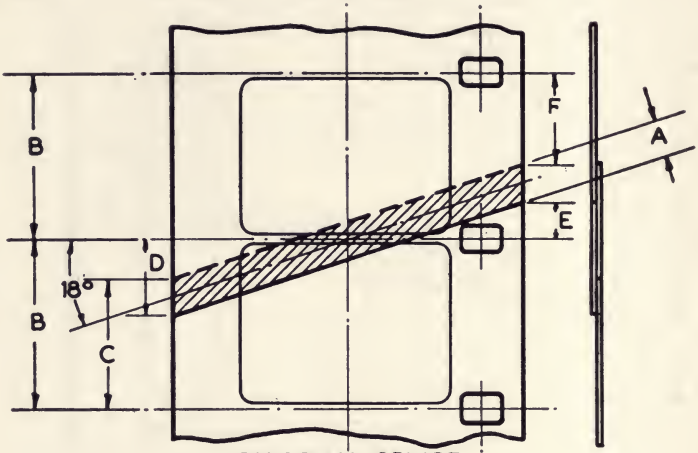
DIAGONAL SPLICE



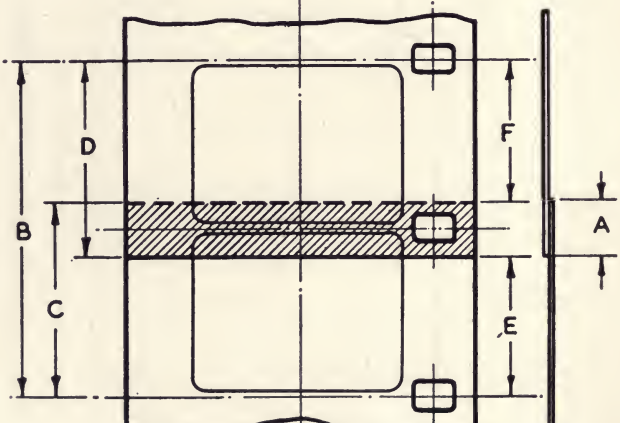
STRAIGHT SPLICE

	Diagonal		*Straight*	
	Mm	*Inch Equiv.*	*Mm*	*Inch Equiv.*
A	1.78	0.070	2.54	0.100
B	7.62	0.300	15.24	0.600
C	5.97	0.235	8.89	0.350
D	3.53	0.139	8.89	0.350
E	1.65	0.065	6.35	0.250
F	4.09	0.161	6.35	0.250

Same as ASA Z22.25 1941	SMPE RECOMMENDED PRACTICE For 16-mm Motion Picture Sound-Film FILM SPLICES NEGATIVE AND POSITIVE	SMPE-33 1936



DIAGONAL SPLICE



STRAIGHT SPLICE

	Diagonal		*Straight*	
	Mm	*Inch Equiv.*	*Mm*	*Inch Equiv.*
A	1.78	0.070	2.54	0.100
B	7.62	0.300	15.24	0.600
C	5.97	0.235	8.89	0.350
D	3.53	0.139	8.89	0.350
E	1.65	0.065	6.35	0.250
F	4.09	0.161	6.35	0.250

Same as ASA Z22.26 1941	SMPE RECOMMENDED PRACTICE For Motion Picture Film SENSITOMETRY	SMPE-34 1934

The principle of non-intermittency shall be adopted as recommended practice in making sensitometric measurements.

Same as ASA Z22.27 1941	SMPE RECOMMENDED PRACTICE For Motion Picture Film	SMPE-35 1938
	PHOTOGRAPHIC DENSITY	

The integrating sphere shall be used as a primary instrument for the determination of photographic density. Photographic densities determined by means of this primary instrument shall be used as secondary or reference standards by means of which densitometers of other types may be calibrated.

Same as ASA Z22.28 1941	SMPE RECOMMENDED PRACTICE For Motion Picture Film	SMPE-36 1938
	PROJECTION ROOMS	

Projection Lens Height.—The standard height from the floor to the center of the projection lens of a motion picture projector should be 48 inches.

Projection Angle.—Should not exceed 12 degrees.

Observation Port.—Should be 12 inches wide and 14 inches high, and the distance from the floor to the bottom of the openings shall be 48 inches. The bottom of the opening should be splayed 15 degrees downward. If the thickness of the projection room wall should exceed 12 inches, each side should be splayed 15 degrees.

Projection Lens Mounting.—The projection lens should be so mounted that the light from all parts of the aperture shall traverse an uninterrupted part of the entire surface of the lens.

Projection Lens Focal Length.—The focal length of motion picture projection lenses should increase in $^1/_4$-inch steps up to 8 inches, and in $^1/_2$-inch steps from 8 to 9 inches.

Projection Objectives, Focal Markings.—Projection objectives should have the equivalent focal length marked thereon in inches, quarters, and halves of an inch, or in decimals, with a plus (+) or minus (−) tolerance not to exceed 1 per cent of the designated focal length also marked by proper sign following the figure.

(Complete plans for projection rooms are contained in *J. Soc. Mot. Pict. Eng.*, Nov., 1938, p. 484.)

Same as ASA Z22.29 1941	SMPE RECOMMENDED PRACTICE For 35-mm Motion Picture Film	SMPE-37 1938
	PROJECTION SCREEN DIMENSIONS	

Sizes of screens shall be in accordance with the table below.

The spacing of grommets shall be 6 inches, with 12 inches as a possible sub-standard. The ratio of width to height of screens shall be 4 to 3.

The width of the screen should be equal to approximately $^1/_6$ the distance from the screen to the rear seats of the auditorium. The distance between the front row of seats and the screen should be not less than 0.87 foot for each foot of screen width.

Screen Sizes

Size No. of Screen	Picture Width (Feet)	Picture Height, Feet	Inches	Size No. of Screen	Picture Width (Feet)	Picture Height, Feet	Inches
8	8	6	0	25	25	18	9
9	9	6	9	26	26	19	6
10	10	7	6	27	27	20	3
11	11	8	3	28	28	21	0
12	12	9	0	29	29	21	9
13	13	9	9	30	30	22	6
14	14	10	6	31	31	23	3
15	15	11	3	32	32	24	0
16	16	12	0	33	33	24	9
17	17	12	9	34	34	25	6
18	18	13	6	35	35	26	3
19	19	14	3	36	36	27	0
20	20	15	0	37	37	27	9
21	21	15	9	38	38	28	6
22	22	16	6	39	39	29	3
23	23	17	3	40	40	30	0
24	24	18	0				

	SMPE RECOMMENDED PRACTICE For 35-mm Motion Picture Film	SMPE-38 1941
	PROJECTION SCREEN BRIGHTNESS	

The brightness at the center of a screen for viewing 35-mm motion pictures shall be 10^{+4}_{-1} ft-lamberts when the projector is running, with no film in the gate.

	SMPE RECOMMENDED PRACTICE For 35-mm Motion Picture Sound-Film	SMPE-39 1938
	SOUND TRANSMISSION OF SCREENS	

A loss of 2.5 db as given by the average response curve at 6000 cps relative to the 1000-cycle response as recorded, is a desirable limiting value for existing types of sound equipment. Screens that meet this requirement are usually found to attenuate 4 db at 10,000 cps. As to regularity of response, variations greater than ± 2 db would not be tolerable. No limits for regularity have been established for frequencies lower than 300 cps.

Same as ASA Z22.30 1941	SMPE RECOMMENDED PRACTICE Definition for Motion Picture Apparatus	SMPE-40 1930
	NUMBER OF TEETH IN MESH	

The number of teeth in mesh with the film (commonly referred to as "teeth in contact") shall be the number of teeth in the arc of contact of the film with the drum of the sprocket when the pulling face of one tooth is at one end of the arc.

Same as ASA Z22.31 1941	SMPE RECOMMENDED PRACTICE For Motion Picture Film	SMPE-41 1934
	SAFETY FILM	

The term "Safety Film," as applied to motion picture materials, shall refer to materials having a burning time greater than 10 seconds and falling into the following classes: (*a*) support coated with emulsion, (*b*) any other material upon which or in which an image can be produced, (*c*) the processed products of these materials, and (*d*) uncoated support that is or can be used for motion picture purposes in conjunction with the aforementioned classes of materials.

The burning time is defined as the time in seconds required for the complete combustion of a sample of the material 36 inches long, the determination being according to the procedure of the Underwriters Laboratory. This definition was designed specifically to define Safety Film in terms of the burning rate of the commercial product of any thickness or width used in practice. The test of burning time, therefore, shall be made with a sample of the material in question having a thickness and width at which the particular material is used in practice.

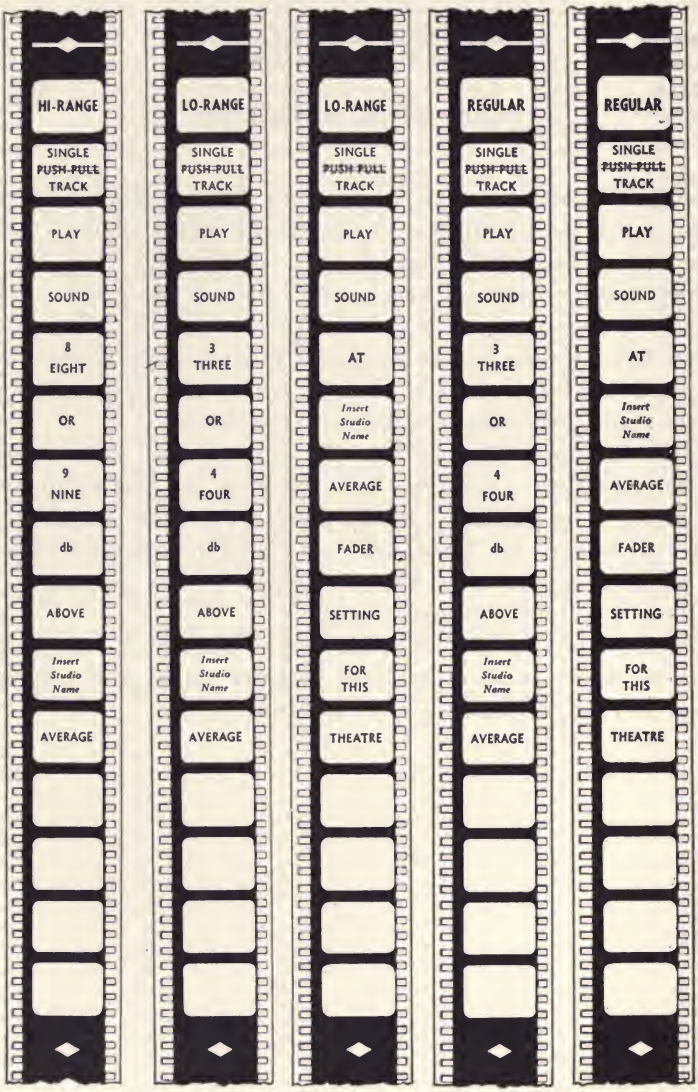
All 16 and 8-mm film must be of the safety type.

Same as ASA Z22.32 1941	SMPE RECOMMENDED PRACTICE For 35-mm Motion Picture Sound-Film	SMPE-42 1940
	FADER SETTING INSTRUCTIONS	

The Fader Setting Instruction Leader shall consist of 15 frames located in the first 20 frames of the synchronizing leader; the first frame shall designate the type of print; the second frame the type of reproducing equipment necessary to project the print; and the next nine frames the general fader setting specified in relation to an average fader setting for the particular product under consideration. The remaining frames may be used for whatever additional information the studio may wish to transmit to the theater.

The designation "Regular" in the Instruction Leader indicates that only one type of print has been issued on the particular production under consideration. Productions with prints designated as either "Hi-Range" or "Lo-Range" are issued in both types of prints, *i. e.*, all productions on "Hi-Range" prints will have necessarily been issued on "Lo-Range" prints as well.

Both the terms "push-pull" and "single" shall be on every leader, one or the other being crossed out to leave the proper term designating the type of sound-track on the print.


HI-RANGE
SINGLE PUSH-PULL TRACK
PLAY
SOUND
8 EIGHT
OR
9 NINE
db
ABOVE
Insert Studio Name
AVERAGE
LO-RANGE
SINGLE PUSH-PULL TRACK
PLAY
SOUND
3 THREE
OR
4 FOUR
db
ABOVE
Insert Studio Name
AVERAGE
LO-RANGE
SINGLE PUSH-PULL TRACK
PLAY
SOUND
AT
Insert Studio Name
AVERAGE
FADER
SETTING
FOR THIS
THEATRE
REGULAR
SINGLE PUSH-PULL TRACK
PLAY
SOUND
3 THREE
OR
4 FOUR
db
ABOVE
Insert Studio Name
AVERAGE
REGULAR
SINGLE PUSH-PULL TRACK
PLAY
SOUND
AT
Insert Studio Name
AVERAGE
FADER
SETTING
FOR THIS
THEATRE

Same as ASA Z22.33 1941	SMPE RECOMMENDED PRACTICE For 35-mm Motion Picture Sound-Film	SMPE-43 1940
	FILTER NOMENCLATURE	

The symbol describing any filter shall consist of three characters, the first designating the frequency of 3-db insertion loss, the second the character "Hi" or "Lo" to indicate high-pass or low-pass, and the third the frequency of 10-db insertion loss (all frequencies in cycles).

Thus the following describes several low-pass filters "4000 Lo 6000" (Fig. 1), "5000 Lo 7000" or "4500 Lo 5500" and the following describe several high-pass filters: "60 Hi 40" (Fig. 2), "80 Hi 30," or "100 Hi 50."

A combination of two of the above symbols may be used to describe a band-pass filter (Fig. 3) or a dividing network (Fig. 4) or a reverse combination of symbols may be used to describe a band-elimination filter (Fig. 5).

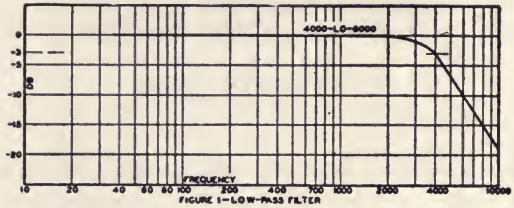


FIGURE 1—LOW-PASS FILTER

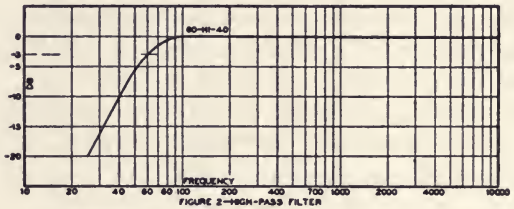


FIGURE 2—HIGH-PASS FILTER

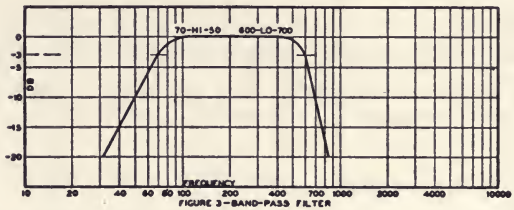


FIGURE 3—BAND-PASS FILTER

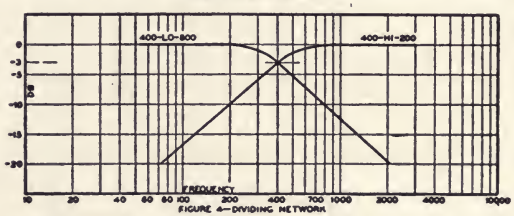


FIGURE 4—DIVIDING NETWORK

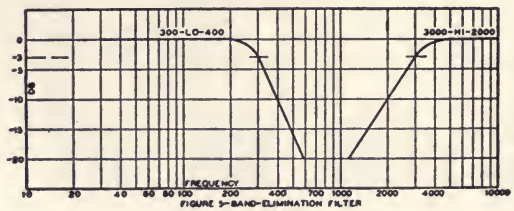


FIGURE 5—BAND-ELIMINATION FILTER

2000-Ft Release Prints*

CHANGE-OVER CUE Four frames containing circular opaque marks, punched similarly to and of the same dimension and position on the frame as the motor cue. Following the change-over cue marks there shall be eighteen frames to the beginning of the runout trailer.

RUNOUT TRAILER

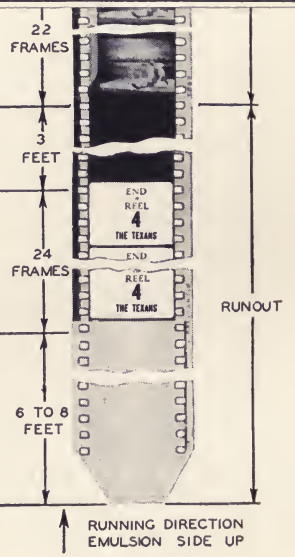
Shall be opaque, 3 feet in length.

IDENTIFICATION TRAILER (End-of-part title)

Shall contain 24 frames in each of which is plainly printed in black letters on white background: (*a*) "END OF REEL," (*b*) reel number (Arabic numeral not less than $1/4$ of frame height), and (*c*) picture title.

PROTECTIVE TRAILER

Same as protective leader.



* Adopted from the Research Council of the Academy of Motion Picture Arts & Sciences, 8th revision, Jan. 6, 1936.

SMPE Recommended Practice
For 35-mm Motion Picture Film

2000-Ft Release Prints*

SMPE-44
1939

PROTECTIVE LEADER

Shall be either transparent or raw stock.

When the protective leader has been reduced to a length of six feet it is to be restored to a length of eight feet.

IDENTIFICATION LEADER (Part Title)

Shall contain 24 frames in each of which is plainly printed in black letters on white background: (*a*) type of print, (*b*) reel number (Arabic numeral not less than $^1/_4$ of frame height), and (*c*) picture title.

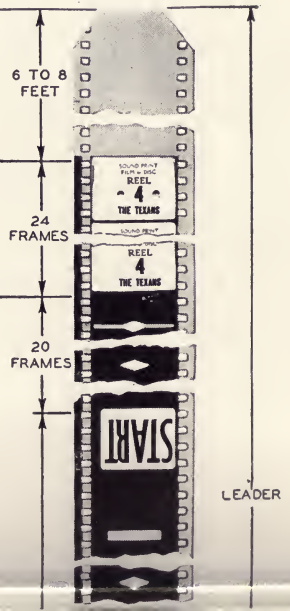
SYNCHRONIZING LEADER

Shall consist of 20 frames ahead of *Start* mark, then 12 feet, including *Start* mark, to picture, opaque except as specified below:

In the center of the first frame there shall be printed across the picture and sound-track area a white line $^1/_{32}$ inch wide upon which is superimposed a diamond $^1/_8$ inch high.

The next 15 frames may be used by the studio for sensitometric or other information. If not so used this leader shall be opaque.

The *Start* mark shall be the 21st frame, in which is printed *START* (inverted) in black letters on white background. The camera aperture height of 0.631



From the *Start* mark to the picture the leader shall contain frame lines which do not cross the sound-track area.

In the frames in which the numerals *6* and *9* appear, the words *six* and *nine* (also inverted) shall be placed immediately below the figure to eliminate the possibility of mis-reading in the projection room due to the similarity between the inverted numerals.

Beginning 3 feet from the first frame of picture, each foot is to be plainly marked by a transparent frame containing an inverted black numeral at least $^1/_2$ frame height. Footage indicator numerals shall run consecutively from 3 to 11, inclusive. At a point exactly 20 frames ahead of the center of each footage numeral frame there shall be a diamond (white on black background) $^1/_8$ inch high by $^3/_8$ inch wide.

PICTURE It is recommended that picture action start and finish on fades wherever possible, otherwise significant sound should be kept at least five feet from the start and finish of the picture.

The length of a standard reel shall be between 1750 feet minimum (except when absolutely unavoidable) and 2000 feet maximum.

MOTOR CUE Shall be circular opaque marks with transparent outline printed from the negative which has had four consecutive frames punched with a serrated edge die 0.094 inch in diameter. The center of these holes is to be halfway between the top and second sprocket-holes 0.281 inch from the right-hand edge of the film with heads up and emulsion toward the observer. Following the four frames containing the circular opaque marks there shall be ten feet, twelve frames to the beginning of the change-over cue.

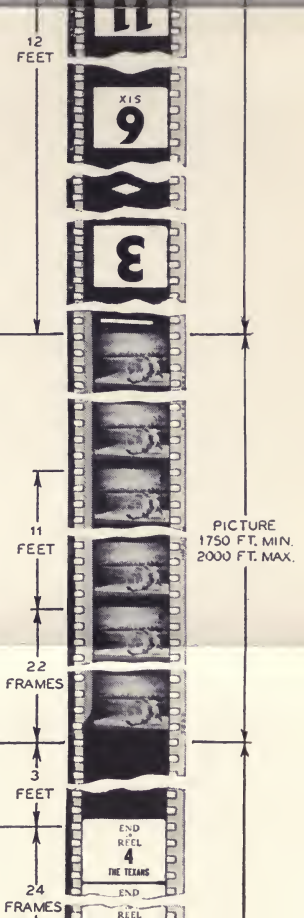
CHANGE-OVER CUE Four frames containing circular opaque marks, punched similarly to and of the same dimension and position on the frame as the motor cue. Following the change-over cue marks there shall be eighteen frames to the beginning of the runout trailer.

RUNOUT TRAILER

Shall be opaque, 3 feet in length.

IDENTIFICATION TRAILER (End-of-part title)

Shall contain 24 frames in each of which is plainly printed in black letters on white background: (*a*) "END OF REEL," (*b*) reel number (Arabic numeral



	INFORMATIONAL DATA For Motion Picture Film	1941
	UNIT OF PHOTOGRAPHIC INTENSITY	

While no standard or recommended practice for a unit of photographic intensity is proposed at this time* the description of an international unit of photography as adopted by the International Congress of Photography in 1928 and 1931 is here given as a matter of information. The resolution passed by the 1928 Congress defining the unit of photographic intensity received the approval of the English and American national committees and of the Optical Society of America. At the 1931 Congress an amendment to the resolution passed by the 1928 Congress was proposed and accepted by the representatives of the various national committees in attendance. So far as can be determined, no official approval by the various national committees was subsequently given. There is therefore a little doubt as to the exact status of this standard as established by the International Congress. The ASA Sectional Committee Z22, Motion Pictures, is at the present time in active coöperation with the ASA Sectional Committee Z38, Photography, in an endeavor to clarify this matter and to formulate a proposal for an American standard for a unit of photographic intensity.

The unit of photographic intensity for the sensitometry of negative materials may be defined as the intensity of a filtered source of radiation having a luminous intensity of one international candle, and produced by a gray body at a color temperature of 2380° (according to the most recent determination of the international temperature scale), together with a selectively absorbing filter made up as follows: Two solutions compounded according to the following formula, the complete filter to consist of a 1-cm** layer of each solution contained in a double cell made by using three pieces of borosilicate crown glass (refractive index, $D = 1.51$), each 2.5 mm thick.

* Reprinted from *J. Soc. Mot. Pict. Eng.* (March, 1941), p. 256.

** Tolerance in thickness shall be ±0.05 mm.

Solution A

Copper sulfate ($CuSO_4$, $5H_2O$)	3.707	gm*
Mannite ($C_6H_8(OH)_6$)	3.707	gm*
Pyridine (C_5H_5N)	30.0	cc
Water (distilled) to make	1000.	cc

Solution B

Cobalt ammonium sulfate ($CoSO_4$, $(NH_4)_2SO_4$, $6H_2O$)	26.827	gm*
Copper sulfate ($CuSO_4$, $5H_2O$)	27.180	gm*
Sulfuric acid (sp. gr. 1.835)	10.0	cc
Water (distilled) to make	1000.	cc

The spectrophotometric absorption characteristics of the filter made up according to these specifications are shown in the following chart,** and in the table below this information is given in numerical form.

The unit of photographic intensity as recommended by the Seventh International Congress of Photography, held in London in July, 1928, was formally approved by the English and American Committees of the Congress and by the Optical Society of America. In ratifying this standard, the Optical Society of America, in order to forestall any possible misinterpretation of the intent of the resolution, presented the following clarifying statements:

"In ratifying this proposal the Optical Society of America understands that the intent of this recommendation is as follows:

(*1*) The intention is to specify two things, (*a*) the unit in which the intensities of light-sources are to be expressed, and (*b*) the quality of light to be used.

(*2*) The unit is to be the International Candle, implying further that the intensities measured and stated will be luminous intensities as in visual photometry.

(*3*) The quality of light to be used for sensitometry of negative materials is to be that which results from passing the radiation from a gray body at 2380°K normally through the filter described.

(*4*) The gray body and the selectively absorbing filter together shall be considered as the effective source in specifying the intensity (candle-power).

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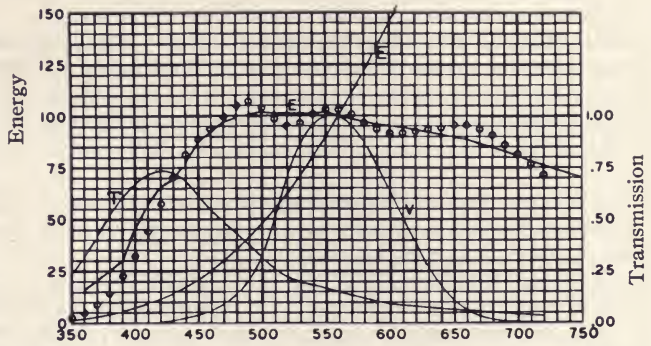
* For practical purposes an accuracy to the second place of decimals is probably sufficient.

** *Bur. Standards Misc. Publ.* No. 114: Raymond Davis and K. S. Gibson, "Filters for the Reproduction of Sunlight and Daylight, and the Determination of Color-Temperature."



λ (mμ)	T	E''*	E''/E'	γ (mμ)	T	E''*	E''/E'
350	0.230	2.5	...	40	0.182	100.6	0.997
60	0.321	4.9	0.304	550	0.167	103.2	1.014
70	0.420	8.7	0.426	60	0.1495	103.1	1.031
80	0.518	14.5	0.579	70	0.1316	100.4	1.021
90	0.608	22.5	0.749	80	0.1151	96.9	0.997
400	0.671	32.3	0.715	90	0.1013	93.4	0.977
10	0.714	44.0	0.767	600	0.0907	91.3	0.959
20	0.737	57.4	0.871	10	0.0834	91.2	0.968
30	0.725	70.3	1.016	20	0.0778	92.3	0.991
40	0.682	81.2	1.044	30	0.0730	93.3	1.012
450	0.612	88.6	1.021	40	0.0684	94.0	1.032
60	0.540	93.9	1.018	650	0.0646	95.1	1.060
70	0.483	99.9	1.031	60	0.0605	95.1	1.074
80	0.431	105.0	1.060	70	0.0558	93.4	1.081
90	0.376	107.1	1.065	80	0.0510	90.5	1.069
500	0.315	103.9	1.020	90	0.0457	85.8	1.038
10	0.259	98.3	0.972	700	0.0409	81.2	1.008
20	0.219	95.0	0.939	10	0.0366	76.4	0.979
30	0.197	96.7	0.957	20	0.0326	71.6	0.940

T—Spectral Transmission of Filter at 25°C

V—Relative Visibility Function

E—Relative Energy of 2360°K

E'—Relative Energy of Mean Noon Sunlight at Washington

$E''(= T \times E)$*—Relative Energy of 2380°K and Filter Combination

Light Transmission of Filter for 2380°K = 0.1352**

* Adjusted to make sum of $E'' - E'$ from 400 to 720 mμ equal practically to zero.

** Factor to be used to multiply the candle-power of the light-source to obtain the candle-power of the source-and-filter combination.

(*5*) The procedure recommended for determining the intensity of the combined effective source is to multiply the intensity of the primary source (gray body) by the appropriate transmission factor of the filter which is 0.135. This factor has been computed from the spectral transmission of the filter *via* the relative energy distribution of 2380°K and the relative visibility function adopted by the sixth session of the International Commission on Illumination at Geneva, 1924.

(*6*) This resolution does not state or imply the value of illumination to be used at the test plane during the sensitometric exposure, nor does it place any limitations on the intensity of the light-source to be used.

Pyridine as included in Solution *A* can, in the opinion of various scientific groups which have investigated the matter, be obtained commercially of sufficient purity to obviate the need for any elaborate precautions and to permit its satisfactory inclusion in the formula for Solution *A*."

THE QUARTER-WAVE METHOD OF SPEAKER TESTING*

S. L. REICHES**

Summary.—*The theory and use of a method for testing loud speakers in theaters are described and presented as a tool for the theater serviceman. Using this method, the serviceman can quickly, and with an accuracy commensurate with his requirements, determine the average frequency response of the speakers, as seen from various points in an auditorium. He can determine also, for a specific auditorium, the horn-system distribution pattern that allows the use of a minimum of acoustic treatment and also the position of this treatment.*

A simple method of loud speaker testing will be described, along with the results of experiments showing its usefulness. This method will be called "the quarter-wave method," since the driving force employs what amounts to a quarter of a sine-wave generated as an exponential voltage pulse. The output of the speaker is measured by amplifying the signal picked up by a microphone, and reading the peak voltage obtained. By this method it is possible to test speaker response *vs.* frequency at various positions in a sound-field when several speakers are employed, and to test the phasing of one speaker relative to the others. Since a single pulse is employed, and only the peak voltage of the pick-up is used, it is possible to test a speaker or set of speakers in their natural locations without interference by echoes or reverberation due to nearby walls.

Application of the Quarter-Wave Pulse.—The quarter-wave exponential voltage pulse is generated by the discharge of condenser C through resistance R in the circuit shown in Fig. 1. This pulse is sent through the amplifier system and applied to the speaker or speakers to be tested. It is true that the pressure pulse communicated to the air by this method can not be strictly represented by an expression of the type $p = p_0 e^{-\alpha t}$. In actual practice, however, the pressure pulse rises sharply to a maximum, then drops off in a more or less exponential fashion. This has been demonstrated by connecting the pick-up to a cathode-ray oscilloscope.

* Presented at the 1941 Fall Meeting at New York, N. Y.; received January 22, 1942.

** The Brush Development Co., Cleveland, Ohio.

The correlation of the quarter-wave exponential pulse with frequency is accomplished as follows: Consider a voltage

$$V = V_0 e^{-\alpha t} = V_0 e^{-\frac{1}{RC}t} (t > 0)$$

and

$$V = 0 \qquad (t < 0)$$

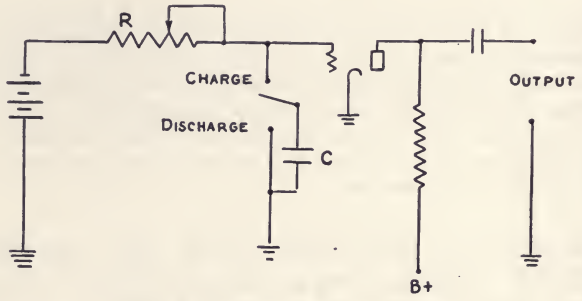


FIG. 1. Quarter-wave generator.

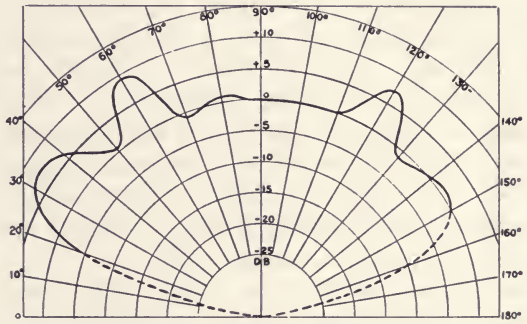


FIG. 2. Distribution curve of outside horns.

applied to a speaker cone. This gives rise to a current $I = (V_0/Z)e^{-\alpha t}$ where Z is the impedance of the speaker. The force on this cone at $t = 0$ will be proportional to $\alpha(V_0/Z)$ (the time rate of change of the voltage) and for $t > 0$, it will diminish by the factor $e^{-\alpha t}$. Since it is known that the pressure communicated to the air by the speaker cone rises sharply to a maximum, we may say without great error that the peak pressure in the air is determined by the force $\alpha(V_0/Z)$. On the other hand, if we had applied a simple harmonic wave $V =$

$V_0 \sin \omega t$ to the speaker, by the same argument as before, the maximum force on the speaker cone would be $\omega V_0/Z$. If we make $\omega = \alpha = 2\pi f$, where f is the steady-state sine-wave frequency, we should expect the same peak pressures in the sound pulses obtained by the two methods. We may then say

$$f = \frac{\alpha}{2\pi} = \frac{1}{2\pi RC}$$

and we have a correlation between the exponential and the sinusoidal excitations.

The Method of Testing.—The quarter-wave generator is connected to the input of the system to be tested. A schematic diagram of such a device is shown in Fig. 1. A pressure actuated microphone is placed in the sound-field at whatever point desired to make a test. The generator is actuated, and readings taken by reading a peak voltmeter connected to the microphone. Readings are taken for the various *R-C* combinations that give the frequencies at which it is desired to make tests. The usual time required to make one set of ten readings is about five minutes; thus tests may be conducted at several points in a room in a comparatively short time.

Tests in the Cleveland Stadium Using the Quarter-Wave Technic.—The public address installation in the Cleveland Stadium presented some interesting problems. For a number of reasons, none connected with engineering procedure, it was necessary to place the horns in a cluster at the foot of the bleachers; these horns are Western Electric Type *598*. At the time this study was begun, the faults were:

(*1*) Insufficient power, even with a partially empty stadium, with 2000 watts of audio available.

(*2*) Low intelligibility due to as many as ten repetitions of the same sound reflected from various parts of the stadium.

(*3*) An effect that might be described as a "rolling-around" of sound between the upper tier of seats and the main floor.

Determination of Improper Phasing.—A pulse equivalent to 350 cycles was chosen as a study frequency. Two considerations suggest the use of 350 cycles—first, the maximum energy of speech occurs around this frequency; second, other factors such as spacing, *etc.*, become equal in importance to the electrical problems at higher frequencies.

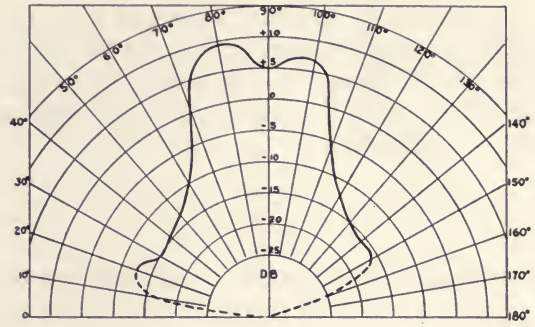


FIG. 3 (*a*). Distribution curve for inside horns.

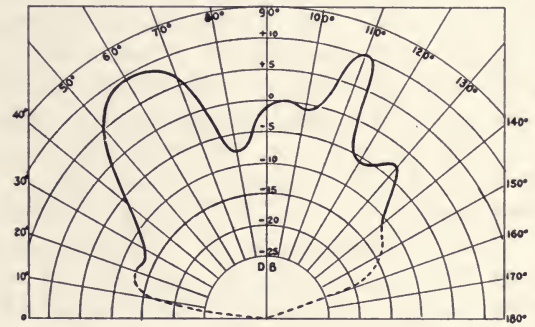


FIG. 3 (*b*). Distribution curve of all horns.

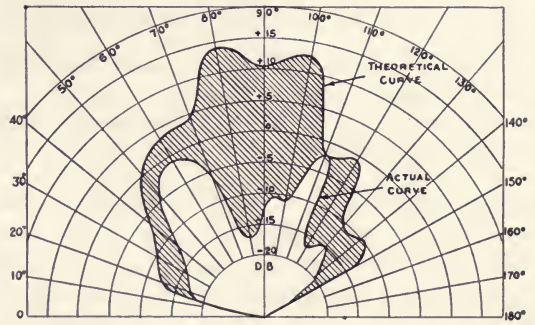


FIG. 4. Comparison of theoretical and actual distribution curves of initial installation.

The distance from the horns for readings was 300 feet. This distance was considered sufficient to insure the complete formation of the beam from all four speakers.

The desired procedure consisted of measuring the distribution pattern of each horn, and by combining these patterns, getting the maximal output in each direction from the combination, then making a comparison between this and the measured combined distribution pattern.

It was not possible to measure each speaker in the stadium separately, as the speakers are driven in pairs by separate power amplifiers, the outside speakers comprising one pair, and the center two another pair. This made it necessary to measure the outside and inside speakers in pairs. These measurements are plotted on Fig. 2 for the outside pair, and on Fig. 3(*a*) for the inside pair. From these patterns it is evident that the speakers comprising each pair are quite well phased. Much interference between the outer speakers would not be expected, even if they were out of phase, since they were pointed away from each other, and were separated quite widely.

Fig. 3(*b*) shows the distribution for all four horns.

Fig. 4 shows the difference between the actual measured curve and the theoretical curve determined by adding the distribution pattern of each pair. The power loss is quite large.

The offending speaker, which was one of the outside speakers, was found to have a transposed field coil. Fig. 5 shows a comparison between the new measured distribution pattern and a new theoretical pattern. (This new theoretical pattern was produced by redirection of one of the speakers.)

The improvement was quite evident. Of interest is the fact that on the same afternoon of the correction only about 500 watts were required to produce the desired loudness with some 25,000 persons present.

Conclusions on Phasing.—Probably this correction could have been made without taking the data shown here. However, there are some interesting points shown by the patterns of Figs. 3 to 5. The most important of these can be seen from Fig. 5. This shows that although all speakers are properly connected, it is not possible to realize the full theoretical power output of all speakers due to their physical spacing and possibly to the variation in electrical phase-shift in the driving amplifiers. There is still much interference.

The Optimal Distribution Pattern.—Every area is associated with a

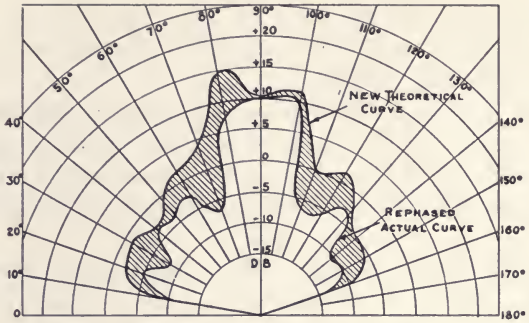


FIG. 5. Comparison of theoretical and actual distribution after rephasing.

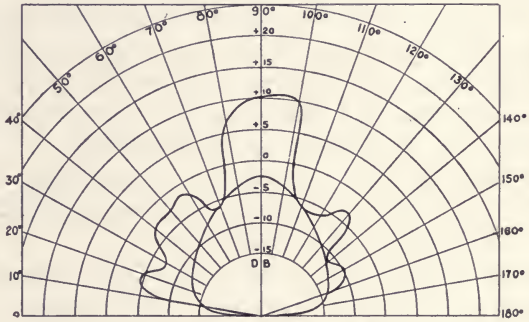


FIG. 6. Comparison of optimum curve with actual curve.

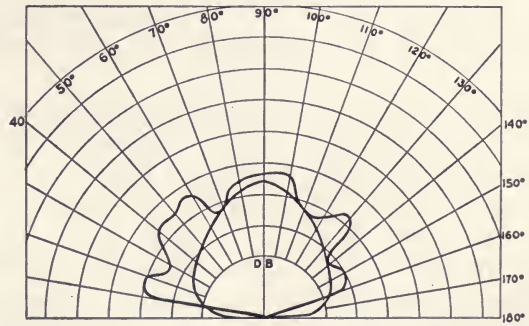


FIG. 7. Comparison of optimum curve with final curve.

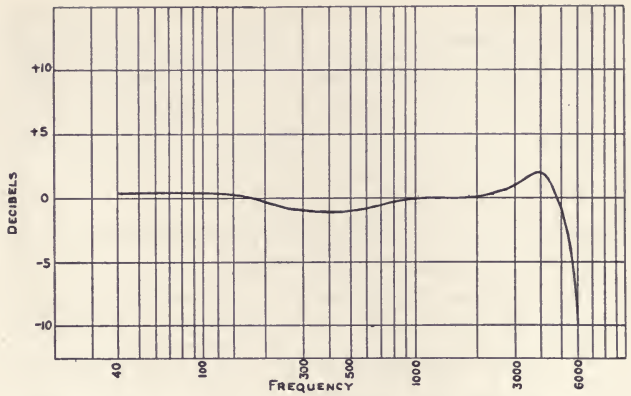


FIG. 8. Frequency characteristics of entire horn system.

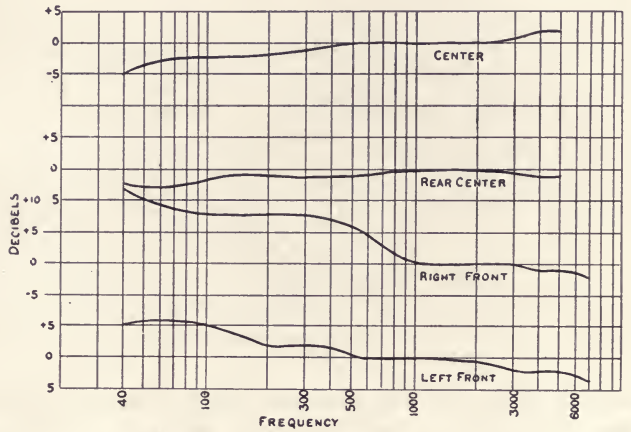


FIG. 9. Frequency characteristics of good sound quality house.

distribution pattern that will produce equal loudness to an observer at all points on the periphery of this area. The desirability of such a distribution is obvious from the standpoint of good listening. This distribution pattern is called "the optimal distribution pattern," that is, the sound at any point on the boundary shall not be too loud for one observer or too soft for another. In addition to this, the optimal distribution pattern will produce the least amount of reflected sound, and thereby the greatest intelligibility. This can be seen from Fig. 6, which shows the comparison between the measured

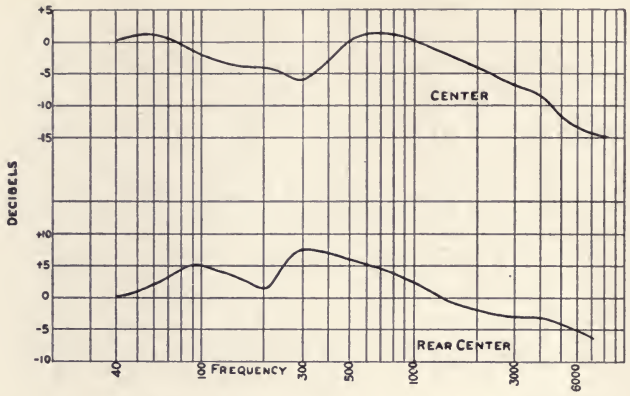


FIG. 10 (*a*). Frequency characteristics of poor sound quality house.

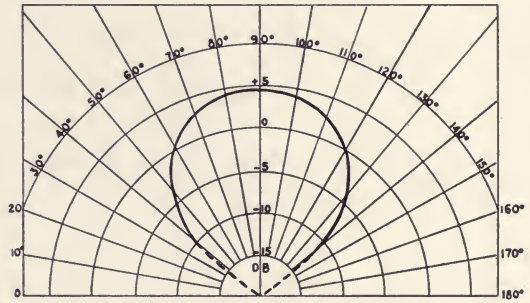


FIG. 10 (*b*). Final distribution curve.

distribution of all four horns, and the optimal distribution pattern for an area the shape of the Cleveland Stadium. The cardioid-shaped optimal distribution pattern was found from the relationship:

$$DB_2 = DB_1 - 20 \log \frac{d_2}{d_1}$$

where

DB_1 = desired level which occurs at greatest distance d_1 from horns.
DB_2 = unknown level at shorter distance d_2.

It will be seen from this that there is a large excess of energy directly down the center of the stadium. This will cause the loudness to be too great in this area, and the reflected sound will be much

greater than necessary. It follows that were acoustic treatment to be applied, the greatest amount would have to be placed in this area.

Fig. 7 shows the final corrected pattern, in which there is some variation from the optimum. The extra level between 10 and 60 degrees was introduced to compensate for the prevailing winds from Lake Erie, the data included here being taken on quiet mornings with no wind.

Conclusions on Optimal Distribution Pattern.—The improvement obtained was quite pronounced even to untrained observers. With the resultant improvement in intelligibility, the apparent multiplicity of source was completely eliminated. This improvement in intelligibility allowed a further decrease in driving power.

It was hoped that some improvement would also be made in regard to the "roll" of the sound. Some observers feel that this was done, but if any improvement was made in decreasing this effect, it was quite small.

The Transient Characteristics of the System.—Exceptionally realistic quality is not looked for in public address work, particularly under the conditions in the Stadium. But from the standpoint of general interest, and also to see the effect of a low-pass filter in the amplifiers, a frequency run was made at a point on a line at right angles to the speaker plane. The distance was again 300 feet, and the result is shown in Fig. 8.

Some Theater Tests.—A certain theater that had rather "good" acoustics was redecorated. In this process, a good-quality lead paint was used on the sound-absorbing material, thereby creating an exceptionally reverberant house. In conjunction with the service engineers, a study was made of the house to see whether an improvement could be made by adjusting the distribution pattern of the horns, and by a study of the transient response of the system.

The frequency characteristics of a system in a house whose acoustic qualities were considered satisfactory were used for reference. Both theaters have identical equipment (W. E. universal bases with type *42* amplifiers driving W. E. *555* horn units).

The data taken are shown in Fig. 9. The two curves with a deficiency of high frequencies were made at the front sides of the house, and the other two along the center. Curves were then run on the poor-quality theater, and these are shown in Fig. 10(*a*).

Before correction was attempted, a reasonably accurate distribution pattern of the house was made; Fig. 11(*a*) shows this pattern.

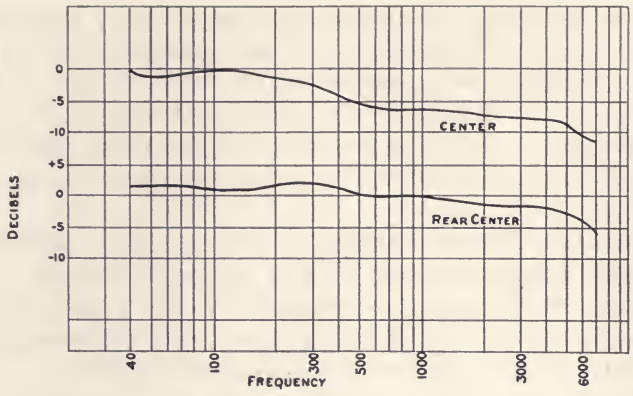


FIG. 11. Final curves after correction.

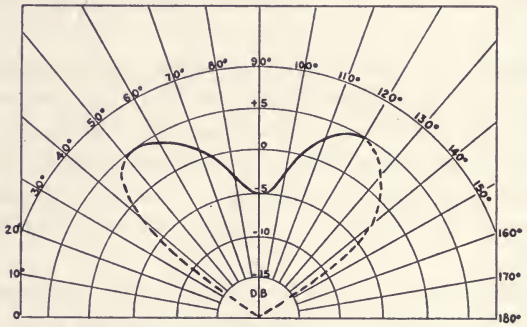


FIG. 11 (*a*). Initial distribution curve.

It will be noted that the greatest level is thrown at the walls near the front of the house.

By using the optimal distribution pattern of this house, the pattern of Fig. 10(*b*) was chosen, and the frequency characteristics of the system were then corrected as shown in Fig. 11.

The results obtained were very satisfactory considering the nature of the house, and were more than acceptable with a half-filled house.

Conclusions.—From these tests on exponential horns and others on the two-way systems, the conclusion has been reached that no one type of horn system is universally adaptable. The requirements for optimal distribution are the best guide in determining the type of speaker system, and once this type is chosen, the most economical placing of absorbent material can be found.

In theaters that are improperly treated, it is often possible to improve the sound quality by adjusting the distribution pattern of the horns.

General Conclusions.—While all the principles involved in the studies presented above are quite generally realized, it is believed that the data contained here are quite unusual in that they show experimentally the action of speaker systems in the surroundings in which they are used. It is further believed that these data could not be taken by any method of measurement other than the quarter-wave method. The warble tone might be used in a small area of a fairly low reverberation period, but in the Cleveland Stadium with a reverberation period as long as 10 seconds the warble tone may be no better than a steady-state tone.

SOUND IN MOTION PICTURES*

NATHAN LEVINSON**

Summary.—*A general résumé of the technical progress in motion on pictures since he introduction of sound. The changes that have occurred in the various technics employed are described, including the different kinds of recording, the achievement of high-quality records and their reproduction, and the improvements in equipment and films.*

PART I

The sound motion picture has not yet attained such an age that many persons will have completely forgotten the thrill which they experienced at their first viewing of a talking picture. Yet in that brief span of approximately a dozen years since the *Jazz Singer* took the country by storm, the technic of recording sound for motion pictures, and the equipment and film stocks employed in the process, have enjoyed an uninterrupted and almost unbelievable degree of development. The practice of making duplicate or triplicate sound records of a scene to insure a single satisfactory finished record has long since been discontinued, and the type of action portrayed on the screen is today in no way limited in scope by restrictions imposed by the recording equipment.

The sound records of the earlier talking pictures were 16-inch disk records, similar in general appearance and composition to ordinary phonograph records. They were recorded at a rotational speed of $33^1/_3$ rpm, to permit a playing time equal in length to the time required for projection of a complete reel of picture. The recording channel proper consisted of several condenser microphones and their associated amplifiers, a mixer table, booster and main recording amplifiers, and a number of bridging amplifiers whose input circuits were multipled across a "bridging bus" formed at the output of the main recording amplifier. The output circuit of each bridging amplifier was connected to the cutting head of a wax recording machine through a calibrated attenuator.

* Reprinted from *Electronics*, XIV (Jan., 1941), p. 17, and XIV (Feb., 1941), p. 37.

** Warner Bros. Pictures, Inc., Burbank, Calif.

The cutting heads employed in the production of Vitaphone records exhibited a frequency-response characteristic which, for a constant input level, produced a record of constant amplitude for all frequencies in the interval between 40 and 400 cps, and a record of constant velocity in the interval between 400 and 5000 cps. The low-frequency response of the cutter was reduced to avoid overloading of the record by the high-energy, low-frequency components normally present in speech and music. The cutter showed a very rapid decrease in response at frequencies above 5000 cps.

The original records were cut on soft wax blanks whose surface had been brought to a high degree of polish by the use of sapphire shaving knives. The production of a good record required the use of a freshly shaven wax blank whose temperature was held within rather narrow limits to prevent smearing or chipping of the wax during recording. The novelty and uncertainty injected in the production of motion pictures by the advent of sound made it necessary to provide means for the director of a picture to check the character of the sound record immediately upon completion of the shooting of each scene. Therefore playback reproducers were provided which permitted reproduction of the record cut in the soft wax. Records which had been so reproduced were, of course, unsuitable for later processing, and for this reason it was necessary to cut two or three records of each scene photographed.

At the completion of shooting and editing of a picture it was necessary to combine the individual recordings of each scene which appeared in the finished picture in such a manner that the single record associated with each reel of the picture would contain just that dialog, music, and sound effects necessary for the scenes appearing in that reel. The process of combining a number of original recordings of dialog, music, and sound effects into a single final record is known as "dubbing," or "re-recording." The difficulty of selecting a few words or sentences from a number of individual disk records and combining these in proper order and in exact synchronism with the action taking place on the screen presented no small problem. In fact, the difficulties of this process of selection and combination were so great that only one of the Hollywood studios, Warner Bros., was ever equipped to re-record from disk records on a large scale.

Nor were the troubles encountered in disk recording ended when the final records for a picture had been completed. The maintenance

of synchronism between picture and sound in the theater was dependent upon accurately placing the theater reproducer at the start mark on the record and simultaneously placing the picture start mark in the picture gate of the projector. If the picture film was torn during projection and had to be spliced, it was necessary to remove one or more frames of the picture from the reel and consequently at each splice in a reel, synchronism between picture and sound was destroyed by an increasing amount. Since the picture and sound record were separate, it was not an unusual occurrence to find the record corresponding to one reel of a picture being reproduced with a different reel of that picture. While this may have tended to create audience diversion during the screening of a dull picture, it helped in no way to maintain the dignity of the theater management. Furthermore, after a certain number of playings the records exhibited a very pronounced loss of quality and often became extremely noisy. All these factors tended to detract materially from the technical and entertainment values of a picture and were responsible in no small measure for the change from disk recording to sound-on-film recording.

RECORDING ON FILM

The recording channel employed for producing the early film sound-track was practically identical to that employed for producing disk records. The signal output of the bridging amplifiers was merely delivered to the film-recording machine instead of to the wax cutting head. While differing in many details, all film-recording machines provide a light-tight housing in which the film is exposed, magazines for the unexposed and exposed stock, means for moving the film at a uniform speed past a light-beam which exposes the film, in accordance with the wave-form to be recorded, the light-source, modulator unit, and the optical system.

The sound-track produced on film varies in width from 76 to approximately 100 mils and occupies a position adjacent to one set of the film sprocket-holes. All track may be broadly classified as being of either the variable-density type or variable-area type and each possesses certain advantages and disadvantages not possessed by the other. Two methods of producing variable-density track were employed during the early period of film recording. In the first, typified by the Aeo-light recording at one time extensively employed by the Fox Studios, the signal to be recorded modulated

the light produced by a gaseous discharge tube and the resultant variable-intensity illumination was photographed on the uniformly moving film in the recording machine after being passed through a very narrow fixed slit. The second and more widely used method of producing variable-density track involves modulating a beam of constant intensity light by means of a light-valve and photographing the illuminated variable-width slit formed by the light-valve ribbons on the moving film. This type of record subjects each point on the sound-track to an exposure of constant intensity, but of a duration determined by the character of the signal being recorded.

Variable-area track is produced by permitting the light from a constant-intensity source to strike the mirror of a galvanometer, and after reflection therefrom, to pass through a narrow slit of fixed width, through a suitable optical system and then upon the sound-track being exposed. Oscillations of the galvanometer mirror, which are produced by signal currents corresponding to the sound to be recorded, cause the light-beam striking the recording slit to illuminate a greater or lesser length of that slit. The sound-track produced by this process of recording is essentially an oscillographic trace of the signal currents.

Although the average early sound-on-film records were little, if any, better from a quality standpoint than the disk records which they replaced, they so facilitated the production, editing, and projection of sound pictures that by 1931 practically all sound recording was being done on film. Editing the sound record of the finished picture was tremendously simplified, since the process of intercutting various sound-track sequences presented no greater problems than intercutting the corresponding picture sequences. This, of course, resulted in enormously simplifying the process of re-recording. It was now only necessary to provide reels of properly intercut dialog and properly intercut reels of music and sound effects and to re-record these in synchronism with the picture to provide a single reel of final negative. Film recording provided other advantages, however, which were scarcely less valuable than the improvement possible in re-recording methods. Unlike the requirements in wax recording where many precautions were necessary, the film-recording machine could be placed at a considerable angle and be used through a wide range of temperature with no change in quality of the finished record. The light-valves or galvanometers, once properly adjusted, are comparatively rugged devices and require much less frequent inspection

and maintenance than wax cutting heads. Perhaps the only single outstanding advantage of wax over film records lies in the fact that the wax record may be immediately played back for checking purposes, whereas some interval of time must elapse between the recording process and the time at which completely processed prints from the film record are available.

The introduction of acetate disk recording early in 1934 effectively supplemented film recording by providing playback records of much greater useful life than soft wax records and having the further advantage of possessing more desirable physical properties than wax. Continuous improvements in acetate disk coating, as well as improved designs of cutting heads and reproducers now make it possible to produce acetate recordings which are almost equal to high-quality film recordings.

Playback records are no longer employed for checking the recording of individual scenes of a picture, but find their greatest application for reproduction, on the set, of music which has been pre-recorded for certain scenes of a picture. The process of pre-recording is employed primarily as a means of saving time on the set for such scenes of a picture which involve the photography of action which must be accurately synchronized with the musical score. For example, during the production of elaborate musical numbers involving complicated dance routines, straightforward production technic would demand that the director of the picture divide his attention between the action proper, the performance of the orchestra employed, and the degree of synchronism maintained by the various groups involved in the complete scene being photographed. A flawless performance on the part of the actors could be rendered worthless by a slight error on the part of some member of the orchestra, while a perfectly performed musical score might be rendered valueless by imperfect synchronism of action on the part of the principals appearing in the scene. It is obvious that the difficulty involved in securing a completely satisfactory record of such a scene is greatly increased by the number of the performing groups. The process of pre-recording the musical score for such scenes in a picture and reproducing these records on the set while the action is being photographed relieves the director of all concern regarding the orchestral performance, and permits both the director and the principals involved to concentrate their attention on securing a perfect performance. Since the record may be reproduced a number of

times with the same results, the scene may be reënacted until a perfect performance is secured. The motors employed for driving the playback reproducer and the camera on the set are electrically interlocked, so absolute synchronism between the photographic and sound records is assured.

During the early period of film recording, the quality of the records produced was very much inferior to that of present-day sound-track, and it is interesting to consider in some detail the numerous improvements in recording equipment, technic, and materials which have made possible the present type of high-fidelity recording.

The variable-density type of record is essentially a halftone photograph of the recorded sound-wave. It will be evident, therefore, that undistorted reproduction of a variable-density record can be obtained only when the entire range of exposure is restricted to the straight-line portion of the H&D characteristic of the film employed, and when the overall gamma of the print sound-track, as appreciated by the phototube in the sound-reproducing mechanism, is equal to unity. Although the science of sensitometry was well developed long before the advent of the sound picture, little use had been made of it in the processing of motion picture films, and the sudden demand made upon the laboratory for proper processing of sound-track necessitated an overnight revision of processing control methods. While it was possible for an experienced person to judge the quality of a picture negative by inspection with sufficient accuracy for practical purposes, this method was wholly inadequate for the determination of proper sound-track processing, and had to give way to accurate sensitometric control of both negative and print development. The introduction of the Eastman type II*b* sensitometer in 1931 was of great value in the study of sound-track processing, since it provided a means of accurately and consistently impressing a series of known exposures on the film whose characteristics were under investigation. So powerful a tool did sensitometric control provide that within a few years after its introduction for sound-track purposes, it was almost exclusively employed for the control of both sound-track and picture processing in the laboratory. As a result of this step, the degree of uniformity and general print quality prevailing throughout the motion picture industry today, is almost unbelievably higher than that existing in 1930.

One of the most disturbing characteristics of the earlier film sound records, was the high level of film background noise. The average

level of this noise was determined by the unmodulated track density in the case of the variable-density record, and by the width of the clear portion of the unmodulated sound-track in the case of the variable-area record. The noise level of a typical unmodulated sound-track was seldom more than 30 to 35 db below the maximum sound level that could be obtained from a fully modulated track. As a consequence, those intimate scenes in a picture which required the use of relatively low level dialog or background music suffered greatly during reproduction. The introduction of sound-track employing noise reduction in 1930 extended the volume range of the sound record by 10 to 15 db and made possible sound-on-film recording with a much greater volume range than that which could be obtained on disks. Basically, noise reduction on variable-density film is secured by making the average transmission of the print sound-track proportional to the amplitude of the sound being recorded at any given instant. In variable-area sound-track, to reduce noise, the average width of the clear portion of the track is made proportional to the amplitude of the sound being recorded at any given instant.

At approximately the same period during which noise reduction was being adopted, the technic of recording had become sufficiently standardized so that some thought could be given to the improvement of frequency characteristics and to microphones, amplifiers, and theater speaker equipment. The first of the Western Electric moving-coil microphones and of the RCA velocity microphones were made available to the industry in 1930. Whereas, it had been necessary to mount the microphone amplifier employed with the condenser microphone as close to the microphone as practicable, the moving-coil and ribbon-type microphones permitted a considerable length of cable between the microphone and the microphone amplifier. Microphone boom construction was correspondingly simplified and considerably greater ease of following action on the set with the microphone resulted. In addition, both the new microphones exhibited very much better frequency-response characteristics than did the condenser microphone.

The first of the so-called wide-range recordings was released in 1932. These served to indicate not only the added naturalness which could be achieved by extending the frequency range, but, and what was probably more important, brought to the attention of the equipment manufacturers and recording engineers the high de-

gree of distortion that existed in the various components of the recording and reproducing channels. Whereas the earlier standard recordings in many cases exhibited quality which was somewhat telephonic in character, the extended-range recordings exhibited an unpleasant boominess and excessive sibilance which was extremely annoying. Investigations which followed indicated the necessity for equalizing the recording channel in such a manner as to decrease the low-frequency response on dialog recordings. A portion of this equalization has been found necessary to compensate for the difference between the dialog level existing at the position of the microphone during recording and the higher reproduction level existing in the theater. Another portion of this equalization, somewhat variable in amount, appears necessary to eliminate boominess, or low-frequency reverberation, of studio sets. Within the past few years, some thought and study have been directed to the determination of the character and amount of recording channel equalization necessary to compensate for variations in speech effort and corresponding changes in spectral energy distribution of the actors' voices during their performances.

Changes in degree of channel equalization and the insertion of low and high-pass filters of various sorts did little more, however, than reduce the degree of objectionable distortion existing during projection. It, therefore, became necessary to investigate in detail the distortion characteristics of each component of the recording system as completely as possible. It was soon found that few, if any, of the amplifiers employed in the recording channel were nearly as free of distortion as had been assumed and a long program of amplifier redesign was undertaken. New distortion testing equipment made it possible to analyze accurately the amount of distortion caused by the recorder modulator units and by film processing, while further studies indicated the need for higher-powered, lower-distortion theater amplifier and speaker equipment.

Amplifier distortion was reduced to an acceptable value by the use of transformers having improved frequency-response and impedance characteristics, by the use of larger vacuum tubes, by judicious use of negative feed-back and in cases where considerable power output was required, by the use of carefully balanced push-pull stages. The development of heater-type vacuum tubes had progressed to a stage which permitted the design of completely a-c operated amplifier equipment for the entire recording channel. As a result of these

improvements in design, the amplifiers employed today have extremely low signal distortion at full recording levels and have excellent frequency-response characteristics. The bridging amplifier employed by Warner Bros., for example, has a gain of 11 db at 1000 cps, with a maximum deviation from this value of but 0.3 db between 30 and 12,000 cps, and will deliver a power output level of +22 db referred to six milliwatts with a distortion of less than 0.5 per cent at all frequencies between 60 and 8,000 cps. The combined hum and noise level of either of these amplifiers is approximately −85 db with respect to six milliwatts.

The distortion introduced by the recording machine modulator unit has been brought to a satisfactory low value by redesign of the light-valves and galvanometers and by decreasing the effective width of the recording slit image on the film. Further reduction of distortion in original recording has been made possible by the use of push-pull sound-track. It is interesting to note that one of the first patents on push-pull recording was issued in 1911, but no practical application was made of this method in motion picture production until 1935.

In Class *A* push-pull recording two sound records are photographed side by side along one edge of the film, one being 180 degrees out of phase with the other. Each of the tracks is in itself similar to a standard sound-track and by combining the signal resulting from the two sound-tracks out of phase, the even order distortion components introduced by undesirable film and processing characteristics are practically eliminated.

Class *B* push-pull recording differs from Class *A* in that each of the individual tracks recorded contains only one-half of the sound-wave form. That is to say, all the positive half-cycles of the sound-wave are recorded on one of the tracks and all the negative half-cycles of the sound-waves are recorded on the other track. During reproduction of Class *B* sound-track the original wave-form is obtained by proper re-combination of the wave-forms appearing on the two sound-tracks.

PART II

One of the principal requirements which must be satisfied by the recording and reproducing mechanisms of a sound motion picture system is that of providing absolutely uniform motion of the film as it passes the light-beam in the recorder and in scanning beam in

the reproducer. Non-uniform motion of the film in either case causes frequency modulation of the signal and is particularly objectionable during the reproduction of music or relatively long sustained tones. The frequency modulator, or "flutter," is particularly noticeable when caused by rapid acceleration and deceleration of the film. The newer recorder and reproducer drive mechanisms have been designed to eliminate this type of distortion of providing free-running film-loops between the pull-down and take-up sprockets and the point of scanning. Critically damped film-driven recording and reproducing drums support the film at the point where it passes the recorder or reproducer light-beam. Heavy flywheels are provided on both the recorder and projector motors to reduce to a minimum any variations in motor speed, and all gears employed for speed reduction purposes are carefully ground and fitted to avoid generation of speed variations by the gear mechanisms.

The recording machine designed by RCA utilizes a very simple, but most effective, means of securing uniform film motion. The driving motor is coupled through gears to a magnet structure which rotates coaxially with, but independently of, a heavy flywheel mounted on the end of the recorder drum shaft. The magnet structure is driven at a slightly higher angular velocity than the normal velocity of the recording drum. Eddy currents induced in the rim of the flywheel cause the drum shaft to rotate at such angular velocity that the peripheral velocity of the drum is just equal to the normal average film velocity through the recording machine. In normal operation of the recorder, a free-running film loop exists on either side of the recording drum, and exposure of any point on the film occurs at a point midway along the wrap of the film on the drum. This mechanism provides an extremely high degree of stabilizing action since there is no direct mechanical drive of the film at the actual point of exposure. This type of recording machine introduces the equivalent of 0.03 to 0.10 per cent frequency modulation as compared with 0.2 to 0.7 per cent of the older machines.

The earlier printers used for producing positive sound-tracks by contact printing from the negative were found to be a prolific source of both frequency and amplitude modulation. A part of the difficulty was insufficient contact between the negative and print stocks. Slippage of the positive film with respect to the negative at the instant of print exposure also contributed to the difficulty. The non-slip printer design introduced in 1936 provided a means of practically

removing film slippage during the printing operation. Present-day sound printers provide very positive means of maintaining an extremely high degree of contact between negative and print stocks and utilize an exposing light-beam whose width is of the order of 0.005 to 0.008 inch. By restricting the length of the sound-track exposed at any given instant, the effects of such slippage as may still occur are greatly minimized.

ULTRAVIOLET LIGHT RECORDING

The extension of the recorded and reproduced frequency range requires utilization of the maximum resolving power of the film. Research on methods of securing increased negative and print definition led to the introduction of a method of recording and printing which utilizes a narrow band of illumination in the near-visible ultraviolet region. When the image of a narrow slit illuminated by white light is photographed on film, microscopic inspection of the developed image reveals the fact that exposure of the film has taken place through the entire thickness of the emulsion. Scattering of the light within the emulsion and reflection of light from the film base result in the spreading of the image beyond the boundaries of the slit. If, however, the slit is illuminated with ultraviolet light and the photographic image of the slit microscopically examined, it is found that the developed image lies almost wholly on the surface of the film emulsion. This occurs because the ultraviolet light is very rapidly absorbed in passing through successive layers of the emulsion and consequently exposure of the entire emulsion depth is much less readily obtained. Correspondingly less scattering of the light within the emulsion takes place, and a very much sharper photographic image of the slit is obtained.

The change from white light to ultraviolet recording is accomplished by filtering all the visible radiation from the light-source in the recorder, and using a lens system that freely transmits wavelengths as short as 3500 Angstroms. Sufficient ultraviolet radiation is obtained from the standard incandescent lamps to secure fully exposed sound-track from the ultraviolet portion of the spectrum alone.

The light in the printing machines also is filtered to eliminate the visible portion of the spectrum and exposure of the print stock is obtained solely by ultraviolet light.

The application of ultraviolet light to the recording and printing

processes has reduced the high-frequency losses to less than 40 per cent of the values which were obtained with white light. In addition, the lower distortion resulting from improved wave-form on the film has resulted in much more pleasing reproduction of high-frequency sounds. The reduction of image spread obtained through the use of ultraviolet light has also made it possible to increase the density of variable-area sound-track prints from an average value of 1.25 to approximately 1.60. This has resulted in a somewhat lower background noise in the theater.

A very simple method of determining optimal processing conditions for variable-area sound-track has been devised which involves the recording of a 9000-cps signal modulated at a frequency of 400 cps. All of the 400-cps modulation is removed from the carrier signal before the test recording is made, and optimal processing is assured when no 400-cps tone is evident during reproduction of the test recording. Fundamentally, this method of testing enables such a choice of print density that the image spread occurring in the print cancels that which exists on the negative. A somewhat similar method of testing the linearity of the overall processing of variable density sound-track has been introduced by ERPI.

LOUD SPEAKER SYSTEMS

Most of the early theater speaker systems employed large horns equipped with one or more motor units behind the screen. While the efficiency of some of these speakers was reasonably high, they were deficient in both low and high-frequency reproduction. One of the early attempts to overcome the defects of the theater speaker employed three speaker units: one for reproduction of the very low frequencies, one for reproduction of the middle range of frequencies, and one for the reproduction of the extremely high frequencies. Suitable dividing networks inserted between the power amplifier and speaker terminals provided proper energy distribution to the three speakers. Considerable difficulty was experienced with such systems in properly phasing and positioning the individual speakers so that uniform distribution of energy throughout the theater auditorium could be obtained. Recent developments in speaker design have given us the two-way speaker system which employs one or more dynamic speakers in suitable baffles for reproduction of all frequencies below about 300 cps, and a multicellular horn equipped with one or more speaker units for reproduction of all frequencies

above 300 cps. This type of speaker installation has become standard in all of the studio review rooms and in all recently equipped theaters throughout the country to provide satisfactory reproduction of all frequencies between 50 and 7000 cps.

The volume range that may be obtained from a high-quality variable-area sound-track, such as employed by Warner Bros., is of the order of 50 db. For many years it was assumed that naturalness of sound in the theater was more or less proportional to the reproduced volume range which could be secured from the sound print. It has since been found, however, that it is an easy matter to provide too great a volume range for satisfactory theater reproduction. The general noise level which exists in a theater, caused by normal audience movements, heating systems, ventilating systems, and operations in the projection booth, determine the minimum sound level necessary for a high degree of intelligibility. The type of scene portrayed on the screen and general comfort of the theater patrons, on the other hand, determine in a general way the maximal sound level which may be employed. Studies of a large number of theaters have indicated that the difference between the maximum level and the minimum level varies between 25 and 35 db. Since the volume range existing in the original dialog and music recorded for a picture is usually considerably in excess of 40 db, it is evident that satisfactory reproduction in a large variety of theaters can only be obtained if an arbitrary reduction in volume range is accomplished. To this end, electronic volume compressors are installed in each of the recording and re-recording channels at the studio, and are normally operated so that the original volume range of 50 db is compressed to a final volume range of the order of 30 db.

The compressors used in recording are essentially amplifiers whose gain is controlled by the instantaneous peak value of the signal passing through the amplifier. Gain control is effected by rectifying a portion of the signal current and impressing the rectified voltage on the control grids of a pair of remote cut-off amplifier tubes in the compressor units. The time-constants of the rectifier circuits are so chosen that a change in gain of the compressor is accomplished in approximately one millisecond.

FILMS FOR RECORDING

A résumé of developments in the sound-recording field would be incomplete without reference to the advances made in the manufac-

ture of film stocks for recording purposes. The early variable-density sound-negative records made at Warner Bros. Studio were recorded on Eastman type *1301* positive film stock with development carried to a gamma of approximately 0.4. This film was originally designed for use as a print stock, the development of which would be carried to a gamma of 2.0 to 2.4 and was, therefore, somewhat low in sensitivity for recording purposes. In September, 1932, the Eastman Kodak Company made available type *1359* recording stock which had a speed of approximately 2.5 times that of the type *1301* emulsion. This increase in film speed made it possible to reduce the recorder exciter-lamp current by an amount that increased the lamp life several hundred per cent, and decreased the variation in negative sound-track density which had previously been caused by lamp instability.

The *1359* type emulsion was used by Warner Bros. until the introduction of ultraviolet recording in 1936. At this time the advantages of employing variable-area ultraviolet recording appeared sufficiently great to justify a complete change in plant recording equipment and the RCA variable-area machines were installed. At this time Eastman made available their type *1357* emulsion which had approximately twice the speed of the type *1301* emulsion to ultraviolet light and this stock is employed for sound negative at the present time.

On October, 1937, Eastman type *1360* fine-grain positive film was tested as a negative recording stock and found to be somewhat superior to the type *1357* film in both high-frequency response and background noise. A number of productions were recorded employing this stock for the sound negative until it was determined that similar improvements could be obtained by utilizing this stock for prints employed for re-recording purposes.

In December, 1939, Eastman announced the replacement of the type *1360* emulsion by the type *1361*, a film of somewhat lower inherent contrast, and of such spectral sensitivity as to permit handling it under positive-type safelights. In all other respects this film is similar to the type *1360* emulsion and results in an increased high-frequency response of approximately 1.5 db at 9000 cps and a reduction in film background noise of approximately 6 db.

In order to provide negatives from which release prints can be made in the various countries, and to provide insurance against the possible destruction of the original picture and sound negatives, it is customary to prepare duplicate negatives of the picture and sound-

track negatives by photographic means. The process involves making a composite master print from the picture and sound negatives and by a second printing operation, securing a composite duplicate negative of the original. Until recently, the composite master print was made on Eastman type *1362* lavender stock and a "dupe" negative was made from this on Eastman type *1217* panchromatic negative stock. Prints made from the duplicate negatives, when compared with the original, showed an average increase in film background noise of approximately 5 db, a loss in volume of approximately 2 db, and a reproduction loss of 6 db at 9000 cps.

In the latter part of 1937, Eastman introduced its fine-grain duplicating positive stock, type *1365*, and a fine-grain duplicating negative stock, type *1203*. These films have been substituted for the lavender positive stock and panchromatic negative stock previously employed in making duplicate negatives and prints from this new stock show an increase in surface noise of only one db, a loss in sound level of one db, and a loss in high-frequency response of only one db at 9000 cps as compared to the original. This improvement in duplicating stocks represents a remarkable achievement in film manufacture and permits the production of prints from duplicate negatives that can not be distinguished from prints of the originals.

It is evident that the exercise of the greatest care and use of the latest recording equipment and materials will be of little value unless the improvements achieved in recording can be reflected in the quality of reproduction obtained in the theater. Warner Bros. has recently completely re-equipped its entire chain of theaters with the latest type of RCA reproducing equipment. This change involved the installation of new type sound-heads equipped with rotary stabilizers to secure uniform film motion at the point of scanning, new amplifiers of greater power handling capacity and lower distortion than those previously employed, and two-way loud speaker systems capable of reproducing, with a minimum of distortion, the entire audio spectrum recorded on the sound-track. While the majority of the theater reproducing units are of very rugged construction, highest quality of reproduction can be obtained only if the reproducing equipment is frequently checked and serviced. This work is accomplished by a theater engineering service group, and by this means it has been found possible to remove likely sources of trouble or partially defective equipment before a break-down occurs during a performance.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C., at prevailing rates.

American Cinematographer

23 (Feb., 1942), No. 2

Movies Speed Training of R. C. A. F. Fighting Airmen (pp. 54–55, 84) — W. STULL

The Electroplane Camera (pp. 56–57) — E. P. HOLDEN, JR.

Color Television in England (p. 58) — J. H. BAIRD

Motion Pictures in the Army (pp. 69, 84–86) — R. B. KONIKOW

Shooting Technicolor in the Air (pp. 60–61, 86–88) — E. G. DYER

Roy Kellino Films Britain's War Effort (p. 62) — W. G. C. BOSCO

Improvising Telephoto Lenses (pp. 72, 93) — P. R. NELSON

Electronic Engineering

14 (Feb., 1942), No. 168

Stereoscopic Television (pp. 620–621) — J. L. BAIRD

Frequency Modulation. Pt. IV—Frequency Modulation Receiver (pp. 628–630, 643) — K. R. STRULEY

Educational Screen

21 (Feb., 1942), No. 2

Motion Pictures—Not for Theaters, Pt. 34 (pp. 61–63) — A. E. KROWS

Institute of Radio Engineers, Proceedings

30 (Feb., 1942), No. 2

Radio Progress During 1941, Pt. 1 (pp. 59–61) Electronics; Pt. 4, Frequency Modulation (pp. 65–66); Pt. 5, Television (pp. 66–67); Pt. 6, Facsimile (pp. 67–68); Pt. 9, Radio Wave Propagation (pp. 68–69)

Factors Governing Performance of Electron Guns in Television Cathode-Ray Tubes (pp. 103–105) — R. R. LAW

Kinematograph Weekly (Ideal Kinema Section)

299 (Jan. 15, 1942), No. 1813

Kinema Technique and Equipment. The Outlook for 1942 (pp. 7, 9) — R. H. CRICKS

Transportable Projectors (pp. 9, 12) — R. H. CRICKS

FIFTY-FIRST SEMI-ANNUAL CONVENTION

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

HOLLYWOOD-ROOSEVELT HOTEL
HOLLYWOOD, CALIF.
MAY 4th–8th, INCLUSIVE

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HEADQUARTERS

The Convention headquarters will be at the Hollywood-Roosevelt Hotel. Excellent accommodations have been assured by the hotel management at the following *per diem* rates:

One person, room and bath	$3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, one person	8.00–14.00
Parlor suite and bath, two persons	10.00–16.00

Room reservation cards were mailed to the membership early in April and should be returned to the hotel immediately to be assured of satisfactory accommodations.

Registration headquarters will be in the hotel lobby. All members and guests attending the Convention will be expected to register and receive their Convention badges. The registration fees are used to defray the expenses of the Convention, and coöperation in this respect is requested. Identification cards will be supplied, which will serve as admittance to all scheduled or special sessions, studio visits, and trips, and several *de luxe* motion picture theaters on Hollywood Boulevard in the vicinity of the hotel.

Members planning to attend the Convention should consult their local railroad passenger agents regarding train schedules, rates, and stop-over privileges *en route*. For a stop-over at San Francisco the Convention Committee recommends the Mark Hopkins Hotel, on "Nob Hill." Accommodations may be arranged with Mr. George D. Smith, manager of this hotel.

An interesting color-print exhibit will be an adjunct to the Convention and will be open to the public and delegates during the five days of the Convention.

The Convention hostesses promise an interesting program of entertainment for the visiting ladies. A reception parlor will be provided as their headquarters at the hotel.

Note: The Pacific Coast Section officers and managers gave serious consideration to the question of holding the 1942 Spring Convention at Hollywood, and have decided to proceed with arrangements for the meeting. The motion picture industry plays an essential part from the exhibiting and engineering viewpoint in upholding the morale of the general and theater-going public in the present crisis, and accordingly the Convention and Local Arrangements Committees are porceeding with their plans. However, if later deemed advisable in the National interest, the Convention will be subject to cancellation thirty days prior to the announced Convention dates.

ABSTRACTS OF PAPERS

FOR THE

FIFTY-FIRST SEMI-ANNUAL CONVENTION

HOLLYWOOD-ROOSEVELT HOTEL
HOLLYWOOD, CALIF.
MAY 4–8, 1942

The Papers Committee submits for the consideration of the membership the following abstracts of papers to be presented at the Spring Convention. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate discussion. The papers presented at Conventions constitute the bulk of the material published in the Journal. The abstracts may therefore be used as convenient reference until the papers are published.

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J. L. Forrest	G. E. Matthews	W. V. Wolfe

Audio-Visual Aids to Naval Training; William Exton, Jr., U.S.N.R., Bureau of Navigation, Navy Department, Washington, D. C.

The expansion of the Navy requires expansion in personnel as well as in materiel. The expansion in personnel means the provision of literally hundreds of thousands of men trained in the operation of complicated equipment. This includes radio, various types of ordnance equipment, navigation, the handling of ships, tactics and maneuvers, the maintenance and repair of all sorts of equipment, aeronautical operations of every kind, and every other activity connected with naval affairs.

Naval training is usually conducted by skilled officers, both commissioned and non-commissioned. At present, experienced and skilled officers who might normally be assigned to training duties are required for operations at sea. At the same time, the number of men to be trained has increased enormously, and the number of fields in which they must be trained has also increased because of the development of new technics and materiel. Furthermore, new inventions have brought about the need for training in fields in which there is virtually no experience and concerning which only a few experts have knowledge.

The Navy believes that the use of audio-visual aids will be of tremendous help in this connection. These can not entirely replace the skilled and experienced officer or non-commissioned officer, but they have certain very definite advantages. One of these is the standardization of instruction, so that men trained at every activity will have interchangeable skill. Another is the supplementing of

the instructor who may not have had much pedagogical experience or be an able teacher, although he may have ample knowledge of the subject. The third is the stimulation of the interest of the trainees. It is possible through visual aids to give them a more comprehensive picture of the application of the technic they are learning to general naval operations than is normally possible during training. Furthermore, since ships are not now available for training purposes as they are during peacetime, audio-visual aids make it possible to give some conception of the application of the subject in which training is being given to actual operations. The armed forces of the United States, guided by such considerations as these, are carrying the use of audio-visual aids for training purposes beyond civilian experience with these media. It is to be hoped that the experience gained and the technics developed will be of value in the future for civilian purposes.

Motion Pictures: Technology in Art; L. S. BECKER, Warner Bros. Pictures, Inc., Burbank, Calif.

The motion picture and the automobile were born at the turn of the century and grew up together. Both have their foundations in science and technology, and both have profoundly affected our individual and national lives. Their maturity has placed them among the five largest American industries, yet one is fundamentally an art. An automobile is something concrete, tangible, something real; a motion picture is light and shadow, laughter and tears, speech and music. The motion picture is an art as well as an industry. The motivating forces of the film are drama, comedy, human experience—yet it could not exist except for the organized efforts of the many craftsmen and technicians that make it an industry. Since art and industry are so interwoven, a change in technology affects the art of the film, while the demands of the art bring about technical improvements.

This report illustrates the role that technology plays in the conception of the film as an art, and the changes that the demands of the art itself have brought about in technic. The cameraman's universal focus, the soundman's reverberation chamber, the set designer's cloth ceiling—all have their share in telling a story realistically and dramatically. Someone's story idea sets this intricate machinery in motion, and from the writer, actor, artist, and engineer comes a living entity—a combination of arts that have been in development since man first learned to record his experiences for posterity.

Motion Picture Laboratory Practices; JAMES R. WILKINSON, Paramount Pictures, Inc., Hollywood, Calif.

The function of laboratory service to studio production departments and to the release distribution field is discussed. The size and scope of laboratory operations are illustrated graphically by an organization chart showing the number of subdepartments. These in turn are classified into three major divisions: namely, control, processing, and maintenance. Analysis of individual department activity begins with the control division, and emphasis is placed upon the recent trend toward the more scientific approach to the problems of processing. The discussion continues with the processing division, starting with negative development. The processing method of each successive department is described, showing the in-line flow of the work for both studio and release print operations.

Problems relating to proper mechanical and electrical maintenance are also discussed.

Re-Recording; L. T. GOLDSMITH, Warner Bros. Pictures, Inc., Burbank, Calif.

The nature of re-recording as it applies to motion picture production is described in some detail by showing what happens to a typical picture in the re-recording department after shooting on the set has been completed and the picture has been edited to the satisfaction of the producer.

Sound is added to those portions of the picture that have been photographed silent because of the difficulty or impossibility of recording the corresponding sound at the time, as, for example, credit titles, montages, miniatures, stock shots, and scenes photographed silent to playbacks of pre-recorded sound. Music that has been specially scored and recorded for the picture together with appropriate sound effects are added to heighten its dramatic presentation.

Improvements in dialog quality are made if required by employing electrical equalizers; although distortion is often purposely introduced where telephone, dictaphone, radio, and similar types of quality must be simulated as required by the picture.

Proper balance of the relative volume of the dialog and the accompanying music and sound effects is determined to the satisfaction of the re-recording supervisor. All the sounds from as many as a dozen or more different sources are re-recorded to a single composite sound-track which afterward is printed with the picture to make up the final print to be projected in the theater.

The organization of the re-recording department is discussed and the duties of the various members of the personnel are outlined. Crews are so made up that an average of from three to six pictures are in work at the same time. A bibliography is included to which the reader can refer for more detailed descriptions of the special equipment and processes employed.

An Analysis of the Complete Sound Recording System Now Used by M-G-M Studios; J. K. HILLIARD, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

This presentation is an illustrated discussion and demonstration of the complete variable-density recording system as used by Metro-Goldwyn-Mayer Studios.

The channel is the result of several years of development and engineering to achieve a high standard of quality and signal-to-noise ratio. The complete system will be described, beginning with the microphone, limiter amplifier, R.M.A. pre- and postequalization, improved coils with special shielding, cylinder lens, noise reduction, improved type headset monitor, fine-grain sensitometry, improved super-portable equipment, new recording machines and re-recording machines, and disk recording apparatus. Engineering specifications and analysis of the design considerations and the functional aspects of the apparatus will be given, followed by a demonstration and informal discussion.

The Development of the Sound-Film, 1927–42; JOHN E. ABBOTT, The Museum of Modern Art Film Library, New York, N. Y.

With the appearance of the part-talking film, *The Jazz Singer*, in 1927, a new motion picture era began. Talking films had been introduced before, but not until then had the electrical engineers solved the problem of amplifying as well as

recording and reproducing sound. As often, technical invention preceded creative use, and at first the new machines were used clumsily. It almost seemed, momentarily, that in gaining a voice the movies had lost a soul. Aesthetic pleasure or intellectual content are hard to find in the first talkies, although the newsreels gained much through the new dimension. The rest was mostly a tinpot substitute for theater. Yet it is well to recall the character of such primitive talkies as *Lights of New York* (the first all-talkie) in order to understand what the elements were that stirred the wonderment and curiosity of the public in 1928, and it is the only effective way of appreciating the speed and ingenuity with which this apparent retrogression in film-making was overcome during the next few years. That it has been overcome completely, even today, is perhaps open to question. The future is certainly rich in potentialities.

In gathering together films of the sound era from many countries for its archives, the Film Library has necessarily encountered some difficulties. It is not generally realized that certain of the early talkies can no longer be projected: either the machinery for running them no longer exists or unequal degrees of shrinkage in visuals and sound-track (often separate then) preclude synchronization today. Even among some pictures of real importance which survive, only poor effects can be obtained. Early sound recording was crude and many factors combine to make renewed experience of *The Love Parade* and *Public Enemy*, for instance, somewhat disconcerting. Audiences following film history at the Film Library's showings can not but be sharply aware of the permutations and improvements in sound recording and reproduction or in the dramatic use of sound and dialog during the early years of sound pictures. They will recognize that unhappy subservience to theatrical form that devitalized the cinema so extensively, and rejoice to see it gradually resume the freer, more cinematic technics of the silent era. Now many famous film stars go into eclipse, while new favorites emerge. Reflecting the world about it, though somewhat belatedly, the cinema has already created the gangster film, but sound gives it startling vitality and familiarizes the English-speaking world with some strange verbal expressions. Now, too, the American film reflects social and political problems, and the trick film reappears. The Russian film, continuing to be seen here mostly by special groups, hardly overcomes the technical difficulties of sound recording, though its directors advance some valuable theories. In France single films flare up again and again to remind us of this country's great contribution to cinematography. By 1934, the film in Germany was harnessed to the uses of propaganda, with results that are important technically and will be valuable historically, though their content, highly repugnant to our national taste, precludes their being publicly shown. As in previous decades, innovations and advances have come about in this country through experiments within the major studios as well as independently in the case of documentary films. Today the motion picture is being used by government everywhere as never before and there is no longer any doubt of the tremendous importance of this medium to society as a whole.

The Production of Industrial Motion Pictures; LLOYD THOMPSON, The Calvin Company, Kansas City, Mo.

The production of industrial sound motion pictures is similar to production in the major studios. Limited budgets mean that certain short-cuts must be taken

but the final screen results must be such that the audience is not aware of the limited budget. If satisfactory results are to be obtained, close coöperation is required between the director who has his special problems and the technical department which also has its special problems.

The paper lists a number of these problems and also discusses what can be expected of industrial producers.

Procedural and Dimensional Practices for Production of 16-Mm Motion Pictures for Television Projection; R. BLACKINTON FULLER AND L. S. RHODES, Marsh Cinesound, Inc., New York, N. Y.

A general report on setting of procedural and dimensional practices for the production of 16-mm sound motion pictures for television projection, including abstracts from discussion with leading television engineers of the major companies for the eventual determination of reproduction standards for equipment and methods that are, at the present time, subject to variations that may impair the quality or clarity of films projected on the television system.

The paper shows that in the various steps from the original film to the final image on the television receiver, a considerable percentage of the frame area is lost by "cropping" in the projector, in the iconoscope, and in the kinescope. Unless this loss is taken into consideration and compensated for in the original planning of films for television, loss of image area may seriously impair the effect of the motion picture.

The paper makes specific recommendations based upon the conclusions drawn, but does not attempt, in view of present conditions, to fix final aperture standards any further than to urge that such standards be set up by the proper group. Many of the factors directly concerned in production are considered with a view to the ultimate quality to be attained.

Reference is made to actual experiences and problems met by the authors in the preparation of animated cartoons and other films for television broadcasting, hoping that their experience may help others to avoid some of the difficulties encountered and thus contribute to the efficiency and effectiveness in the preparation of motion pictures for this rapidly growing medium.

The Practical Aspect of Edge-Numbering 16-Mm Film; H. A. WITT, Wilding Picture Productions, Inc., Chicago, Ill.

The use of the edge number and how it is generally applied in the industry, and the advantages of edge-numbering at 16 frames as a standard for 16-mm film are discussed.

It has been long-accepted practice to edge-number 16-mm film in relation to 35-mm frames. Such practice has proved advantageous in complex films, such as one constructed of some 16-mm film combined with 35-mm to complete a final subject in finished form on 16-mm, still maintaining all the advantages gained in the past practice by the use of 35-mm.

Continuous Replenishment and Chemical Control of Motion Picture Developing Solutions; H. L. BAUMBACH, Paramount Pictures, Inc., Hollywood, Calif.

The chemical reactions that take place in a photographic developer are discussed in detail. It is pointed out that, following the determination of a chemical formula for producing optimal photographic results, the concentration of every

important ingredient of the solution may be held constant by continuous replenishment and chemical control. After a discussion of the theoretical considerations involved, details are given for the establishment of picture negative, variable-density sound negative, and positive systems in use at the Paramount West Coast Laboratory.

The Application of Potentiometric Methods to Developer Analysis; JOHN G. STOTT, Eastman Kodak Company, New York, N. Y.

Potentiometric titration methods are applied to routine developer analyses in order to simplify and speed up the operation and to minimize the "human error" arising from judgment of color change end points, *etc.* A brief theoretical treatment of potentiometric titrations is included, and new tests for elon, hydroquinone, bromide, and carbonate are outlined. Detailed procedure outlines are included along with a discussion of the problem of *p*H *vs.* the alkali content of a developer. A glossary showing stepwise procedure operations required to accomplish the analyses has been compiled along with a complete equipment and chemical reagent list. The precision of the methods is evaluated by a table showing analysis data on carefully mixed known developers.

The Engineering Aspects of Portable Television Pick-Ups; HARRY R. LUBCKE, Don Lee Broadcasting System, Hollywood, Calif.

The routine of portable television programming may be termed "applied" television engineering. This is hardly more than a byplay of words, but it is intended to convey the impression of an engineering technic evolved to put a program across regardless of extenuating circumstances. The emphasis is not on engineering, but on the program, with engineering as one of the tools used in accomplishing the program.

The essentials of the technic are set forth. Proper preparation requires constant servicing of equipment when the latter and the staff are available. A pre-program test several hours before program time is essential to consistent performance, and allows reasonable time for correcting installation or transportation caused faults. A suitable equipment warm-up period precedes the program. Service failures during the program are usually unpredictable but must be met by prompt diagnosis and repair. Thorough knowledge of the many circuits, normal and abnormal operational characteristics thereof, and the knack of finding trouble are requisites of this aspect.

Methodical preparation eliminates some of the difficulties. The television engineering attributes of a program location are tested and recorded prior to the arrival of equipment. Voltmeter, dummy load, photometer, field glasses, and photographic camera comprise the preliminary test equipment. Experiences in televising 140 separate portable programs of the Don Lee Television Station, *W6XAO*, Hollywood, are described.

RCA Audio Chanalyst—a New Instrument for the Theater Sound Engineer; ADOLPH GOODMAN AND EDWARD STANKO, RCA Manufacturing Co., Camden, N. J.

During the past decade, the technic and equipment of the sound device engineer have improved tremendously. Progress in this section of the industry has

kept pace with other developments, until today the methods and procedures in this branch are solidly based upon good engineering practice.

The growth in this important phase of theater operation has brought with it many new and important instruments for more accurate quantitative measurements of equipment performance. This has led to the demand for a light, compact test instrument incorporating the functions of practically all the various instruments now carried by the theater sound engineer. The requirements for such an instrument are met by the RCA Audio Chanalyst. In addition, an entirely new service technic known as Audio Signal Tracing has been made available through use of this instrument.

This means that tests and checks can be made on an amplifier or sound system while the equipment is operating under normal conditions. In tracing the audio-frequency signal, visual and quantitative checks are combined with aural tests. The compactness and flexibility of the Audio Chanalyst decrease the time required to locate troubles, and the engineer is now provided with new devices to allow him to do a more precise and efficient job on a routine service call.

A One-Ray System for Designing Spherical Condensers; L. T. SACHTLEBEN, RCA Manufacturing Co., Indianapolis, Ind.

A spherical condenser is a simple lens of relatively large aperture. The outer portions of such a lens focus the rays much nearer to the lens than do the center portions. As a result the lens as a whole fails to produce a sharp image. This defect is known as spherical aberration. Although no sharp image is produced, an image-like region of maximum light concentration does exist. This is known as the disk of least confusion. Its diameter may be minimized by shaping the lens so as to minimize spherical aberration. It is with this disk of least confusion and its required location that the designer of a spherical condenser must deal.

Without a knowledge of the properties of the disk of least confusion a designer might compute rays through a large number of trial lenses until, by an extensive and costly trial-and-error process, a condenser having the correct shape for minimum spherical aberration, with the disk of least confusion at the required location, may be obtained.

The present paper examines some simple properties of the disk of least confusion. It shows how, by computing the course of a single ray through the proposed lens, a spherical condenser will result having the correct shape for minimizing spherical aberration; having also the correct center thickness for its assumed diameter and edge thickness; and for which, finally, the location of the disk of least confusion is known. The method is applicable to condensers comprising more than one lens, and leads to the required design with a minimum number of relatively simple trials.

Developments in Time-Saving Process Projection Equipment; R. W. HENDERSON, Paramount Pictures, Inc., Hollywood, Calif.

The projection of a motion picture on a translucent screen for background purposes has become increasingly important in studio operations during the past ten years. Many shots now made through the use of this process would have been extremely costly and perhaps impossible if attempted by direct filming of the complete action.

The sharp rise in production costs in the past few years, attributed partly to the foreign market situation, demanded that every effort be expended to simplify production methods.

With this in view, Paramount Pictures embarked upon a complete modernization program of the Transparency Department production equipment early in 1940. New compact projection units, bases for the projectors, rewind tables, screen frames, screen-handling equipment, and light-bridges were designed and built. This equipment has immeasurably simplified operations as well as improved quality beyond levels heretofore achieved.

Specifications and descriptions of this equipment are presented, with emphasis upon a comparison of the new with the old. The success of this equipment can be attributed largely to standardization of component parts. Complete interchangeability of essential units, coupled with easy access to critical points, has gone far toward eliminating lost time and motion in meeting unexpected emergencies.

Cinematography as Practiced in Hollywood, 1942; JOHN W. BOYLE, Hollywood, Calif., in collaboration with others.

The purpose of this presentation is to describe current practice in cinematography as followed in the Hollywood studios. Some of the subjects to be covered are camera equipment, set lighting, operation of camera crews, exteriors and use of booster light, exteriors taken indoors, make-up, diffusion, coated lenses, use of light-meters, color contrast of sets, set and production designers, value of hard light for exteriors and interiors, stand-ins, air photography, matching stock shots, Technicolor and bipack, Kodachrome, and monopack.

The Focusing View-Finder Problem in Television Cameras; G. L. BEERS, RCA Manufacturing Co., Camden, N. J.

The technical excellence of a television program may frequently depend upon the characteristics of the view-finder used in the television camera. Conditions peculiar to television make it desirable that television camera view-finders be of the focusing type. The requirements of an ideal view-finder of this type are discussed. During the past ten years a number of view-finder arrangements have been investigated in connection with the development of television cameras. Several of these are described and their relative merits indicated.

Some Recent Developments in Record Reproducing Systems: G. L. BEERS AND C. M. SINNETT, RCA Manufacturing Co., Camden, N. J.

Several factors of importance in obtaining satisfactory reproduction of sound from lateral-cut phonograph records are considered. An experimental record-reproducing system employing the principles of frequency modulation is described and data are supplied on the measured and calculated performance characteristics of the system. Curves are included showing the vertical force required for satisfactory tracking with the experimental frequency modulation pick-up as compared with other pick-ups of conventional design.

Frequency Modulation Distortion in Loud Speakers; G. L. BEERS AND H. BELAR, RCA Manufacturing Co., Camden, N. J.

As the frequency response range of a sound-reproducing system is extended the necessity for minimizing all forms of distortion is correspondingly increased. The

part that the loud speaker can contribute to the overall distortion of a reproducing system has been frequently considered. A type of loud speaker distortion that has not received general consideration is described. This distortion is a result of the Doppler effect and produces frequency modulation in loud speakers reproducing complex tones. Equations for this type of distortion are given. Measurements confirming the calculated distortion in several loud speakers are shown. An appendix giving the derivation of the equations is included.

The Gasparcolor Process; BELA GASPAR, Hollywood, Calif.

A brief historic review of the photographic multi-layer materials and their elements will be given. The principles of the Gasparcolor Process, the first multilayer material which was introduced to the Motion Picture Industry in 1933 will be described. The process utilizes a positive printing stock which contains dyes in the emulsion layers in the proper densities and color balance; using indifferent treating baths for destroying the dye locally and proportionately to the developed silver image present in the photographic layers. The process uses fast dyes which have good absorption characteristics.

The processing can be carried out with practically the existing facilities of the black and white laboratories, requiring only slight additions. The balancing and printing are similar to black and white procedure, the only variables being the printing lights, keeping the processing time constant.

The various steps in the process will be demonstrated and some of the results shown. A brief discussion of the different taking methods suitable for this process will also be reviewed.

A New Sound Motion Picture Reproducing Equipment for Radio City Music Hall; J. E. VOLKMANN AND J. S. PESCE, RCA Manufacturing Co., Indianapolis, Ind.

The Music Hall has always maintained a high standard of sound reproduction since its opening in 1932. From time to time during this period improvements have been made on the original equipment which was the first commercial high fidelity reproducer to employ the well known rotary stabilizer sound-head that has subsequently become an accepted standard in the industry.

While this is true, still further improvements were felt desirable to enable more forceful presentation of current productions so as to be in keeping with the progress made in film recordings. Among these improvements the following are the more prominent:

(*1*) Greater flexibility between components to facilitate changes in set-ups so as to further enhance presentation and also facilitate service, maintenance and operation.

(*2*) Less distortion and more power output to fully utilize the increased dynamic range of some of the most recent musical recordings.

(*3*) Improved distribution of the higher frequencies through the use of a new type of horn.

A review of these requirements indicate that they could be best met and that it would be more practical to employ standard components of the latest design.

This procedure was followed, and early checks on performance show that these requirements have been met.

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Test-Films.—See advertisement in this issue of the JOURNAL.

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CONTENTS

The Navy's Use of Motion Picture Films for Training Purposes — W. EXTON, JR. — 501
The Motion Picture Camera in the Army Air Forces — G. J. NEWHARD — 510
Wartime Conservation in Theater Projection—A Contribution by the Projection Practice Sub-Committee of the Theater Engineering Committee — 515
The Defense Program of the Motion Picture Theater — H. ANDERSON — 526
Technical Progress in the Motion Picture Industry of the Soviet Union — G. L. IRSKY — 532
The Development of the Sound-Film — J. E. ABBOTT — 541
Edwin S. Porter — 546
Concerning Photography as an Art in America — L. E. VARDEN — 549
Current Literature — 554
Book Review — 557
Highlights of the Hollywood Convention — 559
Program of the Hollywood Convention — 562
Society Announcements — 566
Index of the JOURNAL, XXXVIII (January–June, 1942)
Author Index — 570
Classified Index — 573

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THE NAVY'S USE OF MOTION PICTURE FILMS FOR TRAINING PURPOSES*

WILLIAM EXTON, JR.**

Summary.—*The expansion of the Navy requires expansion in personnel as well as in materiel. The expansion in personnel means the provision of literally hundreds of thousands of men trained in the operation of complicated equipment.*

Naval training is usually conducted by skilled officers. At present, officers who might normally be assigned to training duties are required for operations at sea. The number of men to be trained has increased enormously, and the number of fields in which they must be trained has also increased because of the development of new technics and materiel. New inventions have brought about the need for training in fields in which there is virtually no experience and concerning which only a few experts have knowledge.

The Navy believes that the use of audio-visual aids will be of tremendous help in this connection. These can not entirely replace the skilled and experienced officer, but they have certain very definite advantages. One of these is the standardization of instruction, so that men trained at every activity will have interchangeable skills. Another is the supplementing of the instructor who may not have had much pedagogical experience or be an able teacher, although he may have ample knowledge of the subject. The third is the stimulation of the interest of the trainees. It is possible through visual aids to give them a more comprehensive picture of the application of the technic they are learning to general naval operations than is normally possible during training. The armed forces of the United States, guided by such considerations as these, are carrying the use of audio-visual aids for training purposes beyond civilian experience with these media. It is to be hoped that the experience gained and the technics developed will be of value in the future for civilian purposes.

There are four things necessary for victory in war, with respect to the armed forces. These four things are (*1*) numbers of men, (*2*) equipment, (*3*) training, and (*4*) spirit or morale. If you have enough men, enough equipment, if the men are sufficiently well trained, and if they have the right spirit, you will win. It is the Navy's job to

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received April 6, 1942.

** Lieutenant (jg), U.S.N.R., Bureau of Navigation, Dept. of the Navy, Washington, D. C.

build up its personnel to a sufficient number of adequately trained men of high morale. These men, manning the two-ocean Navy now built and building, can do for the United States what the Navy has always done—protect our shores by defeating the enemy.

There is no doubt that motion pictures have an important part to play in this program. So far as the Navy is concerned, motion pictures are of great assistance in the recruiting program, and undoubtedly help to maintain the Navy as a volunteer organization. Some of you may perhaps not realize that our Navy has never been manned by any other than volunteers. We are proud of that record; and the help that motion pictures give in recruiting assists us in maintaining today that unblemished record dating back to John Paul Jones.

With respect to equipment: equipment, after all, is the product of industry. It is made by men and machines, and is paid for by money. We know that motion pictures assist in raising the money by stimulating the sales of war bonds and savings stamps. And we know that the motion pictures are used in many places to train workers. Many manufacturers of machinery have caused to be produced motion picture training films explaining the use of such equipment. Many industrial organizations employ motion pictures to help stimulate production.

The third of the necessities I have mentioned, however, is the principal subject of this paper, and that is the contribution of the motion picture film to Navy training. I need not remind you that modern warfare is technological warfare. It is men and machines against men and machines. Modern weapons and modern defensive equipment are constantly becoming more complicated. Before the days of firearms, men fought hand to hand, and there was little room for mechanical complication in the wielding of swords and pikes and spears and other such primitive instruments of warfare. The use of these weapons could be learned only through long years of practice. The man who was experienced with one of these weapons was a professional soldier—a mercenary—and a few such men could put to rout many times their number of unskilled and inexperienced peasantry or burghers who were not accustomed to fighting in this manner. With the introduction of gunpowder, there was a tendency to equalize the human beings participating in combat, since a prominent noble dressed in the most expensive suit of armor might easily fall victim to the bullet of a common soldier. Castles that had stood dozens of

sieges over hundreds of years, and were the impregnable homes of prominent lords and monarchs, now fell before booming artillery pieces. But as wars progressed and cannon opposed cannon, complications were introduced to improve the effectiveness of the opposing pieces; and thus the handling of these weapons gradually grew beyond the skill of the average untrained man.

In the early days of our Navy, the range of battle was virtually pointblank, and it took no tremendous skill to aim a gun. The principal skill in battle was that of the commanding officer, who, by maneuvering his ship, brought the other ship within range and exposed it to the deadliest concentration of fire. Today huge shells are sent crashing beyond the horizon, and the swift dive-bomber or high-altitude bomber is prepared to drop its deadly missiles within a few seconds after being sighted. Under circumstances like these, the humblest sailor must—if he is to justify his place aboard a modern vessel of war—be extremely skilled in some useful battle duty. Whether he mans a gun or whether in some high position he spots and helps to control the fire; whether down in the engine room he helps to deliver the essential speed and power; whether he ministers to the wounded, handles the communications, or takes care of the ammunition supply—whatever his battle station, he must perform it with the utmost efficiency, since the total result of the efficiencies of all the participants in battle is the efficiency of the vessel. Nothing less than maximum efficiency can be justified in battle, and such efficiency can not be attained when the personnel is not trained to do its utmost.

However, a modern ship of war, and even a modern warplane, spends a very small fraction of its life actually in battle. In fact it spends a minor fraction of its time even preparing specifically by practice for battle. A large part of the time is spent in maintenance, and in the pursuits that sustain the life and health of the members of the complement of the ship. The members of the gun crew, for instance, spend far more time at maintaining the guns and seeing to it that the equipment is in perfect condition, than they do in firing it. All machinery must be maintained and all the intricate equipment for the control and spotting of gunfire, for communication, for detection of aircraft and undersea vessels, and for navigation must be maintained.

In times of peace a new recruit was sent to a training station for several months of preparation for duty at sea. He was then placed

aboard a ship, where the petty officers above him as well as his commissioned officers would have plenty of time to whip him into shape. He would learn from others by doing, and his drag upon the efficiency of the vessel was not of great importance. In times of war, however, such as the present, a vessel newly commissioned and taking aboard a crew that has never worked together before may find itself in contact with the enemy in a matter of days. Obviously a wholly green and untrained crew can not be allowed to go forth in a war vessel, and yet with naval personnel expanded, as it has been, manyfold in a very brief length of time, the problem of securing trained personnel or of training personnel as secured, is a tremendous one. As the number of war vessels in commission increases, the experienced skilled personnel is diluted, being scattered among the large number of vessels. As more and more ships are required for active duty at sea, fewer of them become available for training purposes.

Thus, though personnel is being expanded beyond all precedent, and the need for training was never greater, there is a smaller number of skilled personnel available to conduct training, and there is less equipment available for use in training. Further to complicate the situation, in a war like the present, there is an astounding development of new technics, of new procedures, new inventions and developments, that require the training of thousands and thousands of men in the use of instruments about which at first perhaps only a very few experts have knowledge.

The training problems created by these situations are tremendous, and in their solution, the visual aids are expected to play and are already playing a very important part. I might observe here that one of the most important characteristics that is desired in naval training is standardization. Men who are graduates of the United States Naval Academy have received standardized training, and thus an officer aboard one American war vessel can generally predict what an officer aboard another Amerian vessel will do under a given set of circumstances. This standardization of training is of great value. Its value extends down into the field of the skilled enlisted men, since the interchangeability of men is of importance to the efficiency of the fleet; and a man who has learned to do a thing a certain way on one ship and is expected to do it another way upon another ship will not be giving to the Navy the fullest benefit of his experience. If men are taught by other men, there is always the tendency away from standardization, since each individual has his

own idea of what should be stressed and how things should be done. However persistently the Navy itself may foster standardization, there is a trend away from standards where teaching is done by individuals.

Audio-visual aids, however, help to standardize. Since they can be used throughout the naval service and since they will appear identically to all who see them, they have the most helpful effect in standardizing training. Furthermore—and this is extremely important—audio-visual aids can standardize training on a high level rather than on an average level. It can not be denied that there are good teachers and bad teachers. Some men are skillful and others not quite so skillful in training men. If audio-visual aids to training are prepared by the best available experts, and are properly designed to have maximum value for training purposes, then training through them can be standardized on a very high level. It is hoped that as the use of audio-visual aids in the Navy develops, this will be increasingly true; and the Bureau of Navigation is extremely desirous of setting and maintaining a high standard for the visual aids produced for use in naval training.

I should like to stress the point that visual aids to training are not entertainment. They are not intended to be entertainment, and they should not be considered as in any way related to entertainment. The mere fact that an audio-visual aid may be a motion picture should not cause it to be confused with motion pictures produced for entertainment purposes. The motion picture is a use of a photographic technic which can serve many purposes. The fact that it has served the purpose of entertainment so greatly should not influence, or better, should not impair its use for training purposes.

There is a tendency on the part of some of those who attempt to produce films for training purposes to make these films approximate films for entertainment. They introduce the films with music, and have music arising many times during the course of the film; and introduce elements of incidental comedy, and in other ways try to make the film, as they would say, palatable.

This is a gross abuse of the principle of the training film. A training film should be regarded as a text-book. It should be easy to understand, it should be clear, it should be simple, it should introduce no unnecessary complications; but there is no obligation on the part of a text-book to be amusing or ingratiating. Furthermore, the proper use of a training film will usually involve its being repeated.

Most of the training films that I have seen can best be used by showing them a number of times, perhaps giving the men opportunity to ask questions or to be lectured to between the showings. A fairly complicated film, which gives the men only a rough idea of the subject the first time it is shown, may be very simple and easy to understand after it has been shown several times, and all the questions asked have been answered, and the subject has been explained. A film that is well conceived and executed will be just as interesting the fourth or fifth time it is shown as the first time, and a new instructional benefit will accrue from each showing; but a film that is made to be entertaining is very likely to look extremely silly the second time it is shown, and thus defeat its purpose.

Those of you whose experiences have been primarily in the field of making films for entertainment should bear this very much in mind if you venture into the field of training film. No doubt many of you will, as this medium achieves greater and greater use in civilian as well as in naval and military training activities.

The Bureau of Navigation has a Training Division. This Division has cognizance over all training of naval personnel, officers, and men. We conduct an extraordinarily large number and diversity of training activities. We run the Training Stations to which the newest recruits are brought for their first experience with the Navy after the Recruiting Station. We run the various schools where enlisted men are taught the trades that make them experts in a very large number of fields. We train the Navy's officers at the U. S. Naval Academy at Annapolis and at the Naval Reserve Officers Training Corps Units in the many universities, and at the Reserve Midshipmen Schools. We conduct the Postgraduate School, and the Naval War College, at which the higher officers receive advanced training. We conduct schools that teach about Diesel engines, underwater sound, radio material, torpedoes, submarines, gunnery, and all the other specialties that modern naval warfare involves.

It is a part of the task of the Bureau of Navigation to find for these many activities the audio-visual aids that will help the officers commanding these schools, and their staffs, to do their jobs as well as possible. The audio-visual aids sent to these many activities come from a great diversity of sources. Officially, the agency for the procurement of photography in the United States Navy is vested in the Bureau of Aeronautics; and if the Bureau of Navigation wishes to procure a film to send to a naval activity, we request the

Bureau of Aeronautics to procure that film. If it is a question of procuring that film by having it produced, then we designate an officer to represent the Bureau of Navigation as our expert in the production. This officer then controls the production, working with the commercial producer contracted with through the Bureau of Aeronautics. In a few instances, the films may be made entirely by naval personnel, since many of our enlisted men are being trained as cameramen, and are being used for various purposes not appropriate to civilians.

Individual naval officers at various places have manifested considerable originality and initiative in developing visual aids for specific purposes. I have seen, for instance, a combination of motion picture, film-strip, and disk recording that was used to teach some of the principles of the detection of submarines by underwater sound. I have also seen an excellent sound film-strip on *Man Overboard Drill*, made by an officer who teaches seamanship at one of our training schools for young officers. There are other examples of this initiative in the development and use of audio-visual aids. The Aviation Service Schools train the many thousands of mechanics needed to serve our naval aviation, and the officers conducting these schools have developed an elaborate collection of visual aids, motion picture films, and film-strips covering almost every subject taught in these schools. They have even developed a series of visual aids for teaching the teachers how to teach. This is useful, since many of the men giving instruction in the Aviation Service Schools have not had previous teaching experience, even though they do know their subjects thoroughly.

All the films produced by the Army Signal Corps or by the Research Council of the Motion Picture Academy of Arts and Sciences for the War Department are reviewed by the Navy, and, if they have an application, are utilized by the Navy. The Navy also uses films produced by other agencies of the United States Government, such as the United States Office of Education. This organization recently produced and is still producing a number of films on machine shop practices, showing how to use various machine tools. These have considerable value, and are used in many of our schools.

There is a number of commercial producers of training films, some of whom have produced films on their own initiative or for the use and distribution of large industrial concerns. Many of these films have been evaluated, and some of them are useful to the Navy. I

may add here that where these films are not confidential in nature and may have applications for public use, they are to be made available for public distribution.

There is another source of training film material, which has not been very deeply tapped as yet, and that is the enormous amount of films that have already been made in one connection or another, and which, by cutting and splicing and editing, can be made into useful training material. There are a number of films made by the British government and for the instruction of the personnel of their armed forces, and some of these have considerable value. All of these are evaluated for naval purposes and the Navy is now using audio-visual aids from all the sources mentioned.

I can not close this paper without referring to the contribution of the motion picture to the fourth of the four essentials to victory that I mentioned—spirit, or morale. The United States Navy has never had to worry about the morale of its men, but that does not mean that the motion picture can not contribute greatly to the maintenance of American naval morale. The motion picture show aboard ship is a regular institution, and it is never omitted if it can be helped. This, of course, is for entertainment purposes, but the motion picture now also serves the purpose of giving to the American bluejacket some idea of our allies—the United Nations fighting side by side with us. The motion picture also helps to remind the American bluejacket of the country that is behind him, of the activities of its civilians, and of the other armed forces, and of the outward manifestations of the basic principles of democracy that are fundamentally involved in this world conflict.

So you can see from this little talk that the motion picture is important to the Navy. You men who are important to the motion picture should remember this and help to make that importance greater, more significant, and ever more contributory toward our eventual victory.

In conclusion, I should like to leave this thought. One of the most important aspects of civilization is the transmission of ideas. The motion picture is, as you know well, a potent factor in this field. Its use for entertainment has been developed to a very high degree; its use in training and in education is only beginning. And yet the application of the motion picture to training and to education may in the end be far more important than any of us imagines at present. Even now it may be of vital importance in building the efficiency of

our armed forces today; and it can surely play a great role in developing the minds and spirits of young and old in the future.

In the past the motion picture industry has not lent its best brains, its greatest talent, its most creative potentialities to the making of films for purposes of training or education. This use of the motion picture film, however, is fully worthy of the closest attention of the ablest technicians and the greatest brains this industry can boast. The rewards may not be measured in dollars to the same extent that the production of films for entertainment may be measured in dollars; but the nature and quality of the contribution made, and the permanent value of that contribution will bring satisfaction that can not be compared with that of the ephemeral success represented by a "hit."

THE MOTION PICTURE CAMERA IN THE ARMY AIR FORCES*

GUY J. NEWHARD**

Summary.—*A brief account of the various uses of the motion picture camera in the Army Air Forces. A number of examples of such uses are given and it is pointed out that new demands coming in regularly make it reasonable to believe that the only limitation of the use of motion pictures in the total war effort will be the number of cameras and cameramen available.*

Despite a complete lack of romance, glamor, and box-office names, regardless of highly technical themes, no one goes to sleep at an official screening in the Motion Picture Branch at Wright Field. Wright Field is the research and development center of our Army Air Forces. Aerial warfare touches the lives and thoughts of every person in the world; no topic holds such universal interest unless it be the day-to-day progress of the war itself.

Civilians rarely see the technical subjects we film. We make movies of tests when the action involved is too fast, too complicated, or too remote for accurate observation with the human eye. The motion picture camera is the one instrument that can capture the full time-sequence of some types of experiments. The same thought must have occurred to the men who made *The Great Train Robbery*.

So, when the pictures of a critical test flash upon our screen, the engineers who usually make up the audience are all attention. Possibly they pay closer attention in case of a failure, because the film will tell them when, and where, and why, and how the failure happened. But never do any of the aeronautical specialists—aircraft engineers, structural and designing experts, engine, propeller, armament, equipment engineers—fail to give full concentration. They make the best audience in the world.

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.; received April 13, 1942.

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The Motion Picture Branch makes all aerial pictures for the Army Air Forces. It also does much work in laboratories and on location at various airdromes, filming unrevealed projects with an unrevealed number of camera crews. Its personnel includes a number of men who have worked in Hollywood, and its development laboratory has much of the latest equipment employed in the industry's shops.

Our camera equipment is most complete. Akeley and Eyemo cameras are used in the air; Mitchells and Bell & Howells for ground work. One to eighteen-inch focal-length lenses are regular accessories. A most complete line of all 16-mm equipment is also used. Three large Fonda developing machines are used, plus rack and tank. Before this year is finished, the laboratory will have processed more than 20,000,000 feet of film, a decided increase over last year's 1,000,000 feet. Depue and Bell & Howell printers are used throughout. Our own optical printer for special effects and four channels of RCA plus two portable units complete our sound department.

It is no secret that the armed forces of every country are making more technical films than ever before, just as a larger number of morale and propaganda subjects are being made for public showing.

To cite a few instances illustrating how motion pictures aptly aid and expedite military aircraft development:

Not many weeks ago an experimental dive bomber crashed during the final tests. The factory test-pilot was killed. Ground observers who watched the new ship drop like a plummet from 20,000 feet in a terminal velocity dive—power dive—advanced various causes which were not in agreement.

From the wreckage film was recovered intact from a camera and this revealed not only the initial cause but clearly pictured the progress of each successive failure, step by step, starting with the pull-out until the crippled plane shattered itself on the ground a few moments later. This film is good "red meat" for structural and design engineers at Wright Field, and in the plants where very high performance airplanes are built.

Much like one would sight in a new gun, new bombardment airplanes are put through bombing practice, using the various sizes of bombs. The purpose is to observe the trajectories of light bombs, which will be a little different from those of medium bombs, which in turn fall unlike heavy bombs.

Excessive turbulence within the bomb bay may cause the bomb to wobble just after it is released from the rack before its fins steer it into

steady downward flight. On such practice missions the motion picture camera records, for the study of armament engineers, exactly what happens. The camera follows the bombs clear down to the target, and furnishes data from which are calculated the number and size of bombs most effective against various targets.

In wind-tunnel tests cameras are used to show how an airfoil twists or bobs and flaps at different air speeds under varying loads. For example, a new design of wing is weighted near the root to simulate different engines in various positions, while farther out on the wing weights are added to represent the machine gun and ammunition load. From a study of the patterns and movements at various speeds, engineers can calculate the most efficient engine position, armament location, and the maximum load the wing can support with safety. Streamlining of airfoils, nacelles, airscoops, and other units has been improved after motion pictures of smoky airflows around the parts suggest a way to improve the design.

Before any new warplane goes into production it is customary for the manufacturer to send what is known as the skeleton article to Wright Field for structural tests. In such tests, bags filled with lead shot are piled upon all parts of the airplane subject to stress in flight, to prove whether the airplane can withstand every maneuver it will be put through in military use. To record the failures that normally come some time after the design load is exceeded, only a high-speed motion picture camera taking 2200 exposures per second can detect where the first failure occurs and follow the path of successive failures as the structure collapses.

The camera is used in another type of test in the Structures Laboratory. This is known as the drop test, in which a fully loaded airplane is dropped vertically from various heights to determine the strength of the landing gear. The film record is obtained by mounting small lights at points from which can be measured the deflection of the tires and oleo struts under impact.

Comparative tests of experimental parachutes with service chutes are made by dropping the chutes simultaneously from an airplane at various altitudes and speeds. Each chute carries a dummy of known weight. On the ground below the cameraman obtains a record from which equipment engineers can tell how long each chute requires to open, how the experimental chute compares in stability and oscillation, and how long it takes to lower a given load to the ground from a known height. The dial of a stop-watch is shown on each frame. If

the experimental chute rips when dropped with heavy load at high speed, the camera record makes the best kind of testimony to show the hopeful manufacturer why he can not be given a contract.

In a similar way, with the exception that cameramen are used in the air as well as on ground, thousands of feet of film are shot during the development of equipment for parachute troops. Every detail of different types of chutes, static cords, jumping technics, cargo parachutes, and methods of laying down large forces of parachute troops around an objective was filmed to detect and eliminate unnecessary hazards due to malfunctioning of equipment.

An assignment from the Chief of the Air Forces to cover the large scale maneuvers down South put our cameramen overhead in photographic airplanes to bring back a panoramic aerial view of the activities of both the Red and the Blue Armies. This film shows the movement and counter-actions of tanks, trucks, troops, and air forces *en masse*. And it discloses whether any of the forces were exposed unnecessarily to attack from the air, whether aerial attacks were executed with full effectiveness, and how the master strategy of each side worked out.

One instance of the camera's aid to aviation medicine may be described. This is the set-up that shows close-ups of pursuit pilots during "blackouts" brought on by tight turns at high speeds, pull-outs after dives and other types of extreme acceleration encountered in aerial combat. Besides the facial contortions and body sagging, instruments in the installation show the airspeed, altitude, duration, and force as some of the details required by the medical officers.

This film does not have the audience-suspense of some of the special-effects shots that were made for *Test Pilot*—unless one knows the conditions under which the official films were made and their purpose.

When chemical warfare experts modify equipment for use in military aircraft, motion pictures are very helpful in finding out the result. For example, here is a job of installing smoke screen equipment in a new and faster type of attack airplane. Assume that the mission of this plane is to streak across the edge of an enemy airdrome a few seconds before the attacking planes come in to bomb and strafe hangars, gas trucks, grounded planes, and defensive gun emplacements. It is highly important that an adequate curtain of smoke be placed to protect the following planes from defensive fire. So the cameraman loads into a rear cockpit for practice runs, and the pilot

lays down smoke curtains around imaginary objectives. In the projection room the chemical warfare officer can readily see whether the smoke screen is high and wide enough for its purpose, and whether it has open gaps. He can then prescribe the operating instructions for the equipment under the various wind conditions encountered in actual combat, and determine the proper capacity.

One of the Air Corps items tested by machine gun fire is the bullet-proof fuel tank. Everything that happens to the bullets and the tanks must be carefully scrutinized by the engineers. Each factor—first contact of the slug on the near side, the hole that is drilled, the change in the shape of the slug, its tumbling motion through the tank, and the jagged hole torn in the far side of the tank as the slug emerges, are all elements that must be considered. A complete test alternates single shots and bursts. The rate of fire of the machine guns is possibly 700 shots a minute. So, while still pictures serve to show what the tank looks like at the completion of the test, it is necessary to use high-speed motion picture cameras to obtain complete data.

As a matter of fact, aircraft guns themselves have on occasion been improved through pictorial evidence secured with a motion picture camera. For example, a certain gun had a slower rate of fire in its early tests than was expected. A series of high-speed motion pictures was made of the gun action, and close analysis showed that one key part was binding. When this was given a little attention the sluggishness disappeared.

Motion pictures have been keeping the historical record of the progress of aviation for over three decades. Perhaps the oldest print in the storage vaults is one made when the Wright Brothers gave a demonstration flight for the Army at Fort Meyers in 1908. Many of the aviation "firsts" since filmed were included in *Cavalcade of Aviation* recently released by Universal.

I have mentioned only a few of the ways in which the motion picture camera is serving the Army Air Forces. New demands coming in each month make it reasonable to believe that the only limitation to the use of motion pictures in the total war effort will be the number of cameras and cameramen available.

WARTIME CONSERVATION IN THEATER PROJECTION*

A CONTRIBUTION BY THE PROJECTION PRACTICE SUB-COMMITTEE
OF THE
THEATER ENGINEERING COMMITTEE

In collaboration with the War Activities Committee of the Motion Picture Industry, Richard Walsh, president of the IATSE, recently announced a ten-point program designed to conserve vital materials needed for military purposes; to salvage such materials; and, by reducing waste to a minimum, enable the motion picture theaters to carry on during the present emergency.

In a message accompanying the printed program distributed to the theaters of the country, Mr. Walsh said, "Our country is at war. Here's how you can help. Every type of material is required in America's war effort. Many materials which you handle every day are scarce. Spare parts are hard to get. Your theaters may have to close unless the equipment that you handle is cared for and conserved. It is vitally important to maintain your projection, sound, and stage equipment in good operating condition. Only in this way can your theater be kept open to do its vital job of maintaining morale. Conserve, Salvage, Eliminate Waste."

The 10-Point Program is as follows:

(*1*) Keep your projection rooms and equipment clean. Dirt causes wear and tear.

(*2*) Lubricate properly all equipment. Follow the manufacturer's instructions.

(*3*) Make only necessary replacements to conserve spare parts.

(*4*) Burn carbons at minimum current specified by manufacturer. Use carbon savers where available.

(*5*) Clean lenses of optical systems with soft tissue and protect condensers and reflectors.

(*6*) Service regularly all electric current distribution points, such as: motors, generators, bus bars, fuses, switches, resistors, and condensers.

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* Presented at the 1942 Spring Meeting at Hollywood, Calif., and at the Meeting of the Atlantic Coast Section at New York, May 21, 1942.

(7) Allow sufficient warming-up period for all vacuum tubes. Burn tubes at specified ratings of equipment manufacturers.

(8) Inspect, thread, and rewind film very carefully. Keep it clean.

(9) Handle reels and film containers with care; these can not be replaced.

(10) *Do Not Throw Anything Away.*

Keep all worn out parts and metal coated carbon stubs; collect copper and other carbon drippings. Keep all burned out or broken vacuum tubes and incandescent lamps. You will receive instructions as to the proper disposal of this salvaged material.

The Projection Practice Sub-Committee of the SMPE Theater Engineering Committee is wholeheartedly in agreement with the ten points and their aims and purposes. However, the Committee feels that the value of the ten points would be greatly enhanced if the projectionists of the country were informed more in detail of the ways and means of accomplishing the ten points. There is much beneath the surface in each of the points, and to bring out clearly all the details underlying the wordings of the points, the Projection Practice Sub-Committee has prepared the following elaboration of the ten-point program. Each of the following sections was prepared by a member of the Projection Practice Sub-Committee and the separate contributions were then correlated to present a clear picture of the great amount of detail that underlies each of the ten points:

(1) *Keep Projection Rooms and Equipment Clean. Dirt Causes Wear and Tear.*—Dirt has been the cause of serious film fires in preventing the proper operation of the automatic fire-shutter or in clogging the fire-valve rollers. It makes them susceptible to wear and renders them useless for the purpose intended.

Dirt may cause the stoppage of sound reproduction by accumulating on the various movable contacts or on the vacuum-tube contacts in the sound equipment.

It may cause losses in screen illumination, when deposited on the projection arc reflector or condensers, and has resulted in the rapid deterioration of carbon contacts with communicated damage to the adjacent parts of the lamp mechanism.

Dirt on the gear-teeth and shafts of the projector, combining with the lubricating oil, acts like a grinding compound, causing excessive wear and shortening the effective life of the gears and bearings.

On fuse-clips it causes high-resistance contacts and the generation of heat, which may sometimes cause the fuse to blow.

Make sure that the lamp house and all parts are kept thoroughly

clean both inside and outside. The carbon ash, drippings, *etc.*, should be removed regularly once a day, especially from the shafts, bushings, and gears of the arc control operating parts.

The arc exhaust dampers and ducts should frequently be cleaned thoroughly of carbon ash, dust, *etc.* Any blockage, no matter how small, will affect the proper burning of the carbons, cause pitting of the mirrors, and produce a gradual accumulation of ash within the lamp house. If there is a filter in the air-supply system, make sure it is in efficient working order. Care should be taken to prevent dust and dirt from blowing into the projection room through any windows if left open.

To get the most out of motor-generators, they should be kept clean, and all dirt should be removed before sparking becomes disastrous. Increased brush life as well as increased commutator life will be the direct result. Dirt on commutators causes arcing and pitting, shortening their life and increasing maintenance costs. The contacting surface of each commutator brush should be periodically examined so that commutator and bearing wear is held to a minimum. If the generator is on a concrete floor, care should be taken in sweeping, so that abrasive dust from the concrete will not get into the bearings. The exhibitor who is interested in keeping his projection maintenance costs low should extend to the projection room the same services used in cleaning the auditorium and other parts of the theater. The projection room floor, walls, and ceiling should be of such materials that they will not "dust off." If the floor is of exposed cement, it should be kept well painted with "dust-proof" or "sealer" paint, and should be mopped frequently. A supply of lintless cloths for cleaning should be made available, as well as other cleaning facilities such as carbon tetrachloride, brooms and dust pan, metal waste can, and the like. In fact, these should be standard equipment of the projection room.

A stiff-bristled tooth-brush is useful for keeping the sprockets and idler rollers clean. The space between the fire-valve rollers and the castings in which they are mounted can easily be cleaned by inserting a narrow strip of film and drawing it back and forth to dislodge the dirt.

(*2*) *Lubricate Equipment Properly.*—Follow the manufacturer's instructions, and use only the grade of oil recommended by the manufacturer. The importance of lubrication of projection equipment can not be overemphasized. Now that metals and oil have become important in our country's war program, we must regard the lubri-

cation problem from the conservation viewpoint as well as the operating.

Projection equipment lubrication carried out properly and under manufacturers' instructions will lead to trouble-free operation.

The use of the proper types of oils and greases and their proper application will give longer life to the equipment and keep the standards of projection on a high plane.

The following rules should be strictly adhered to:

(*1*) Do not lubricate the mechanism while it is in motion. Doing so is hazardous both to the mechanism and to the projectionist.

(*2*) Do not over-lubricate. Excessive lubrication is costly and wasteful. It also impairs the quality of the sound and the picture. Only small oil cans that dispense small quantities of oil at a time should be used.

(*3*) Cleanliness in conjunction with lubrication is an important matter, since excess oil deposits promote the collection of dirt, dust, and grit on the vital parts of the projection equipment.

(*a*) Should the fire rollers become coated with oil, they will collect dust and grit, which will scratch the emulsion on the film. Such marring and destruction of film is very costly, and definitely does not contribute to our war effort.

(*b*) Deposits of oil, grease, and grit on the film strippers cause wearing of the sprockets and damage to the sprocket-holes of the film.

(*c*) Excessive oil on take-up devices causes them to slip, resulting in film mutilation by pile-up or sprocket breakage.

(*d*) All containers of oil should be kept carefully covered, and oil cans should be cleaned before being refilled.

(*3*) *Make Only Necesary Replacements.*—Due to the difficulty of obtaining replacement parts, it will be necessary to make the present parts last longer. The projectionist must assume greater responsibility in his care of the apparatus he operates. This means a daily inspection of the various items of the apparatus to insure to the utmost degree continuous, efficient operation. To a large extent this can be accomplished by systematic care to eliminate abnormal wear.

The projector mechanism has many precision-made parts. To reduce replacements and repairs to a minimum, the projectionist should keep his eyes constantly open for signs of uneven or jerky motion of the mechanism, and his ears attuned to any unusual noises during operation. A good practice is to turn the projector over by hand before the start of each day's show to see whether it revolves freely or not. If it seems to bind, the switch must not be thrown or serious damage may result. With the projector idle, try by hand the meshing of the teeth of the main drive gear, the lower sprocket pinion gear, and the intermediate gear. When the teeth on any or all of these

gears show signs of rapid wear they should be realigned, otherwise new gears will shortly have to be installed.

At least once a week check the synchronizing marks on the vertical shaft gear, the intermediate gear, and on the intermittent movement flywheel to see whether they are in their proper operating relation. Watch the intermittent. Any slack that may develop between the star and the cam, or in cam and flywheel shafts, should be removed and every visible screw should be tightened at least once a month. This will avoid much future trouble.

Care should be taken when removing the intermittent sprocket, movement, or any other delicate part, not to strike the hard surface of the mechanism housing, as the good parts may be burred or jarred out of perfect alignment.

When the intermittent sprocket or star-wheel shows undue wear, tension on the pad or film guide should be checked and the spring compressed or released until the desired tension on both sides of the shoe is obtained. Too much tension wears the sprockets and may damage the film.

The pad rollers should be adjusted by the simple method of placing two thicknesses of standard 35-mm film on the sprocket held tightly over the teeth. The surfaces of the roller should be allowed barely to touch the film, and then the arm is tightened in this position. The rollers should be in line with the sprocket-teeth; that is, the teeth should operate in the recess formed in the rollers. A good practice is to wash the sprocket-teeth at least twice a week with a stiff-haired brush dipped in kerosene, and at least once a month the entire mechanism should be thoroughly cleaned with kerosene to remove all injurious foreign bodies.

Always, when making repairs, or installing gears, make sure beforehand that the proper procedure is thoroughly understood and that guide marks are scribed by hand on the parts or that the factory guide marks match in order to have perfect alignment. Proper tools should be available before starting any such work.

On some mechanisms the stripper plates and sprockets may be reversed when they show undue wear, but such reversing should be done very carefully and after some thought, as in some cases more harm can be done than good.

In the care and maintenance of the sound-head, practically the same precautions should be followed as indicated for the upkeep of the projector mechanism. The many electrical connections should

be frequently checked and tightened. When a rotary stabilizer is used the roller should be left open at all times except when film is running in the projector.

The following list should prove helpful in the care and maintenance of the upper and lower magazines:

Tighten all screws.

Check the bushings, shafts, and reel locks.

Watch the upper magazine tension. Excessive tension causes fast wearing of the upper feed sprocket.

Keep the upper friction spring and collars clean and lubricated. Avoid jerky upper magazine feed.

When readjusting the take-ups, place a heavily loaded reel in the lower magazine. Start the motor, and, beginning with no tension, gradually tighten until the reel picks up and revolves slowly from any position in which it is stopped. Give an extra half-turn to the adjusting knob and lock it.

Do not wait for take-up belts to break. Change belts every thirty days, and allow oil-soaked leather belts to dry thoroughly. Carefully examine removed belts for breaks, bad spots, *etc.*

Ventilating fans in rectifiers require periodic inspection and lubrication from one to two times a year. The rectifier should be located in a well ventilated, cool spot. A free flow of air should be maintained. Avoid placing rectifiers too close to other equipment or placing materials on top of them.

In bulb-type rectifiers, the bulb sockets and clips should be inspected to make sure they are clean and not corroded or pitted. Sandpaper may be used to remove corrosion in order to make good contact. The bulbs should be secure in their sockets, and should be checked every few weeks. The various connections should also be checked.

The power input to the rectifier should correspond to the transformer rating. Voltages should be kept as close as possible to the recommended values. Variations over 10 per cent should be corrected.

A few precautions in the care and maintenance of rewinders, reels, splicers, and electrical change-overs will prove helpful in prolonging the useful life of the equipment.

Rewinder alignment should be checked. Aluminum reels should be handled with care, as new ones are not available.

Realign the splicer and check the cutting blades.

Once a month, check the change-overs and the foot-switches for proper contact and alignment.

(4) *Burn Carbons at Minimum Current Specified by Manufacturer. Use Carbon Savers Where Available.*—It is suggested that motion picture theaters operate projection lamps at or near the minimum arc current recommended for the trim in use if the resulting reduction in screen illumination below that at maximum recommended current can be safely tolerated. The general adoption of this suggestion should result in a considerable power and carbon saving, and for those theaters using copper-coated carbons, a substantial reduction in copper consumption.

It is felt that this suggested reduction in operating current, while bringing the level of screen illumination below recommended practice in many instances, will still permit acceptable projection of motion pictures and, for the duration of the war, is justified by the substantial saving of power and essential materials which can be accomplished in this manner.

Check ammeters and voltmeters in projector arc circuits to be certain they are accurate, before making any alterations in your present operations.

Check into the availability of reliable carbon savers on the market at the present time that will operate satisfactorily in your lamps. Be sure to use most economical carbon combination and length of carbons available for your lamps. Avoid striking an arc too soon.

(5) *Clean Lenses Properly and Protect Condensers and Reflectors.*—Lenses, condensers, and reflectors should be cleaned with special lens tissue or soft cloth. Avoid the use of abrasive cleaning materials or cloths containing fibers that scratch. Condensers and reflectors should be cleaned only when thoroughly cool, as any sudden cool draft may damage the optical system.

Most arc lamps are equipped with inside protective flame shields. These shields should be properly maintained.

Projection optical systems should be cleaned every day before the show. Do not turn the mirror around in its holder, as in a very short time the entire surface will be pitted. Do not attempt to remove pits forcibly. Check the mirror-retaining clips for the proper holding tension; when too tight, the mirror may crack due to expansion.

Port glasses should be cleaned daily.

Treated lenses should be cleaned in accordance with the manufacturer's instructions. Keep oil from reaching the lens element. These instructions pertain to both sound and projection optical systems. Care should be taken to prevent chipping.

(6) *Service Regularly All Electric Distribution Points.—Motors, Generators:* Friction is the greatest cause of wear and tear on all rotating equipment. Anything that can be done to reduce friction will tend to increase the life of all such equipment. It is, therefore, impossible to place too much emphasis on cleanliness of the equipment as well as of the surroundings of such equipment.

In order to prevent dust and dirt from dropping or being blown into the unit itself, all walls as well as the floor and ceiling of the motor-generator room should be painted and cleaned regularly. Lubrication of the unit should be done in accordance with the instructions of the manufacturer and a chart should be kept of such lubrication to show the regularity of such service. Bearings should be drained at regular intervals of not more than six months and refilled with a good grade of oil, of a viscosity as recommended by the manufacturer.

Brush contact should always be good and the tension should be kept at the minimum that will not allow sparking. Brushes should be staggered so as to allow even wear across the entire width of the commutator. Never use brushes other than the grade recommended by the manufacturer.

Keep all slots in undercut commutators clean by the use of a wooden stick of the proper width, and never use oil on any commutator. If necessary to use an abrasive on the commutator, clean both brushes and commutator thoroughly afterward. Keep the shaft and couplings in proper alignment. Blow out all dust and dirt from the windings of the unit with a blower.

Alignment of the motor and generator shafts should be checked and the couplings kept tight. Misalignment and looseness cause vibration, increased wear, and replacements.

Bus Bars, Fuses, and Switches: These do not ordinarily wear out; they generally burn out, and do so because they are not kept clean. Dirt or corrosion causes resistance to electric current, and resistance causes heating; the heat causes additional resistance and a vicious circle is thus built up which eventually destroys the unit. Good contact, therefore, is the first requisite of extended life of these units, and good contact is maintained by cleanliness and tight connections Go over all switchboard connections regularly with proper tools, and if refillable-type fuses are used make sure that all contacts within the fuse itself are clean and tight.

The numerous a-c and d-c switches throughout the projection

room should be inspected at least once a month. The panels should be opened and every nut and bolt, switch, and fuse-holder should be cleaned and tightened.

Resistors: Resistors do not ordinarily wear out if they are properly selected for the duty they are to perform. These units need no special service except to be kept clean, and all connections to them be kept tight. It is suggested that not less than once every six months they be freed of all dirt and dust by the use of a blower. Resistors should be properly placed and adequately ventilated to prevent overheating.

All outside connections on ballast rheostats should be checked. The cover should be removed periodically, and the bolted connections to the resistor material checked. Rectifiers should not be operated above the recommended rating. Once a year, or oftener if necessary, blow out the accumulated dirt and lint in the rectifier stacks. This will insure proper ventilation and cooling.

(7) *Allow Sufficient Warming-Up for Vacuum Tubes. Burn Tubes at Specified Ratings.*—It is important that amplifier and rectifier tubes be pre-heated and become stabilized at operating temperatures before the sound system is operated. Usually a fifteen-minute period is sufficient for this purpose. Certain types of tubes, particularly rectifiers, require a pre-heating period to allow the electron emission to become stabilized so that all parts of the filament are liberating electrons before the plate voltage is applied to the tube. If the plate voltage is applied before sufficient electrons have been emitted, the surface of the filament may be damaged, or part of the filament may be burned away at one spot.

Many of the larger tubes have spiral extension springs to take up the slack of the filament resulting from expansion and elongation due to the heating. Sufficient pre-heating time should be allowed to permit the filament to assume its normal operating position before applying the plate voltage.

Mercury-vapor tubes must be pre-heated to drive the mercury from the filament and plate elements of the tube before applying the anode voltage. This usually requires three to five minutes, depending upon the location of the mercury in the tube and whether or not the tube had previously been pre-heated. Tubes of this type should have an initial pre-heating period of five to fifteen minutes and then used for two or three days. They can then be stored in a vertical position for future use.

Once a mercury-vapor tube has had an initial pre-heating, and all the mercury has been driven off the tube elements, the daily pre-heating period is much shorter than when the tube is first put into operation.

Equipment manufacturers issue instructions regarding pre-heating of tubes where necessary. Follow these instructions carefully.

Tubes should be operated at the voltage ratings specified by the manufacturer. An accurate meter should be used in making these measurements. A majority of installations are provided with a 110- to 120-volt switch to adjust the primary input voltage. If the amplifier or unit is not equipped with a switch of this type, the voltage may be adjusted by moving the tap on the primary of the power transformer. Operating the tubes on line voltages above the normal value will not add anything to the output of the tubes but will only decrease their life. Operating the tubes below their normal rated voltages also shortens tube life.

(*8*) *Inspect, Thread, and Rewind Film Carefully. Keep It Clean.*—Film should at all times be carefully handled. It should be kept away from all sources of heat, except the normal heat during projection. The regulations against smoking should be obeyed.

Film should under no circumstances be left lying exposed on benches or elsewhere, but should be immediately placed in metal containers or cabinet after use.

Film should be inspected each time before it goes through the amchine. The only way that film can be properly inspected is by slowly winding the film by hand. Inspection should cover tears, splices, and defects in sprocket-holes. Do not use bent reels. Use fresh film cement for making all splices.

Film should be carefully threaded through the machine. It should be in proper place on every roller, gate, and sprocket. Excess slack at top and bottom of machines should be taken up before the machine is started. Magazine doors should be closed as soon as the film is threaded and should be kept closed during the entire operation.

(*9*) *Handle Reels and Film Containers with Care; They Can Not Be Replaced.*—A bracket or rack should be erected on which to keep all empty reels instead of allowing them to lie on the floor or elsewhere where they may be damaged.

Film-storage cabinets and shipping cases should be kept clean. Bent reels should be saved, as manufacturers are making arrangements to straighten such reels.

After putting reels into the film cabinet, the compartment door should be closed by hand. It should not be allowed to snap back into place by its own weight. Care should be taken that ends of film do not stick out.

(*10*) *Do Not Throw Anything Away.*—Because of acute shortages of many materials, and the difficulty of obtaining replacements for theater equipment, all broken and worn out parts should be saved.

Save all gears made from steel, bronze, brass, or other material. Sprockets, pad-rollers, blades and jaws of old switches, copper wire, arc-lamp jaws, and other metal parts should be accumulated for disposition at some future date.

Do not throw away a transformer or motor of any kind. The copper can be reclaimed and the cores can be used again. There are some manufacturing concerns who will not ship a new transformer unless the old one is returned.

Broken aluminum reels and other aluminum parts should be welded or otherwise repaired. This is a critical metal, and if the part can not be mended, save the aluminum. Reel and trailer cans should be returned to the film exchanges. Nearly every projection room has an accumulation of these cans which is taking up valuable space. Trailers and sections of film not in use also should be returned to the exchanges, who will then forward the film to film reclaiming companies.

The country needs copper. Remove and save the copper coating from old copper-covered carbon stubs. Save all the copper drippings from copper-coated projector carbons. Provide a metal pail in which to store the copper drippings and the copper plating.

Do not throw out used or defective vacuum-tubes of any kind. There are many valuable metals used in the manufacture of these tubes. Coöperate with the sound engineer in conserving all tubes, and other replacement parts.

Copper wire, rubber-covered cable, and cable plugs will be among the articles hard to obtain. Conserve all your available stock. Fix up all cables and plugs in use at the present time. Save all the old pieces. Provide a box and some space in which to store all defective or burned out electric light bulbs. Each bulb is made of material that the country needs for manufacturing new products.

Keep the accumulation of metal parts by placing metals of one kind in one box or pail and metals of another kind in another box. This will assist in keeping the different metals separated and facilitate in disposing of them when instructions for disposal are received.

THE DEFENSE PROGRAM OF THE MOTION PICTURE THEATER*

HENRY ANDERSON**

Summary.—*Civilian defense involves many technical problems in the solution of which the highly specialized talent of the SMPE may be of great assistance. Theaters in England continue to operate during bombings and it is planned to continue their operation in the United States, due to the important part which they play in maintaining morale.*

New responsibilities have been placed upon theater management, in the preparation of their theaters and the training of their staffs to meet the new emergencies. The Motion Picture Theater Industry has risen to its new responsibilities.

Civilian Defense Engineering is the newest branch of Engineering. Like all forms it overlaps other branches, but it has a sufficient number of unique specialized engineering problems to dignify it as a profession.

In the Society of Motion Picture Engineers there is represented some of the most highly specialized, technically trained talent in the country. There are leaders in the fields of light, sound, color, physics, chemistry, optics, television, radio, who should be able to assist in solving many of the civilian defense engineering problems with which the motion picture industry may be confronted. The Society has offered its services to the industry and to the nation.

The engineer and the scientist are playing an important part in civilian defense activities, such as:

(*a*) Selecting and improving places of safety for civilians in case of air raid. They have studied the effects of explosive bombs, and the principles of construction for bomb resistance. Much technical information has been obtained from England, and extensive tests and research have been carried on here.

(*b*) Notifying the population of the imminence or occurrence of an air raid. This involves the design of alarm systems, sirens, *etc.* There has been much dissatisfaction with the existing outside sirens and many of the local alarm devices.

(*c*) Extinguishing incendiary bombs and fires set by bombs. The fire protection engineer has devoted much skill and research to developing devices for extinguishing incendiary bombs, and for strengthening public and private fire protection.

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.

** Paramount Pictures, Inc., New York, N. Y.

(*d*) Regulating traffic to avoid accidents. Here the traffic engineer has come forward.

(*e*) Restoring public services damaged as a result of raids. This is almost entirely an engineering problem involving repair of lighting, power, fire alarm and similar services.

(*f*) Preparing for and executing blackouts. This is entirely within the province of the lighting engineer.

(*g*) Protecting against gas; designing gas masks, providing gas shelters; decontamination.

(*h*) Demolishing, clearing, and restoring damaged structures, and rescuing persons trapped in fallen buildings.

(*i*) Effecting camouflage. This is a combined architectural and engineering problem, involving also photography.

Our ingenuity is taxed to the utmost today to accomplish these things without undue use or labor and materials, and here the engineer and scientist come to the front.

Civilian defense is directed toward the preservation of civil life and property, through organization of the civilians themselves. There are no sharply defined battlefronts today nor is there a sharply defined line between the civilian and the soldier as far as exposure to danger is concerned. The soldier risks his life in battle, and the civilian may properly be expected to risk his to the extent that military necessity requires.

For complete civilian protection against bombs there would be required shelters, sixty to a hundred feet under ground and of sufficient capacity to hold the entire civilian population. In England, in the early stages of the war, it became obvious that the provision of such shelters was impossible. In the United States, with a coastal zone subject to bombing 300 miles or more deep and many thousands of miles long, to provide such shelters would consume all our productive man-hours and strategic materials and we should have to stop building planes, tanks, guns, and ships.

Where astronomical numbers are involved totals run up quickly. If a stirrup-pump were manufactured for every home in this zone, due to the nature and quantity of materials involved, war production would have to stop. This may be true even of the lowly galvanized-iron pail.

In England, the theaters were closed by the authorities when air raids first occurred. There followed an alarming falling-off in public morale, and the theaters were reopened and have remained open ever since. The authorities in this country came to the decision in the early part of the war that the continued operation of motion picture

theaters is important. We in the motion picture industry were among the first to prepare our properties for defense emergencies, and as a result the civilian defense authorities have encouraged us to regulate ourselves as an industry. In many cities and States there is a separate motion picture theater group headed by a practical theater operator. Of course, in carrying out measures for protection of theaters, we ran into the limitations of avoiding interference with the defense effort, and of a shortage of many needed materials and equipment.

A theater may be one of the safest buildings in the community. Due to lack of window and door openings and its generally substantial construction, it will be highly resistant to bomb fragments. It is provided with a heating and ventilating system, seats, drinking water, and other facilities contributing to comfort and safety.

The authorities urge that the public remain in the theater upon the occurrence of an air raid or air raid alarm. In fact, theaters are generally required to take pedestrians in for shelter in addition to the patrons already in the theater. In England the audience remains in the theater and the show is continued during air raids.

Organization for civilian defense will remain for some time a definite part of theater operation. Management finds a whole new set of regulations under which it must operate. New responsibilities have been placed upon it. A theater manager may have in his care and be responsible for the safety of more persons than is the commander of a battleship. He knows his problems and how to handle theater emergencies better than anyone in the community and should make certain on his own account of the safety of theater audiences.

The first step in the preparation of a theater is cleanliness throughout. A theater is much less likely to be fired by a bomb or incendiarism if combustible material in the theater is reduced to a minimum.

Cleanliness is the first step in any kind of prevention, whether it be accident prevention, fire prevention, or otherwise. Cleanliness once established should be maintained by constant inspection.

Following the clean-up should come the painting or white-washing of out-of-the-way places, dark passages, alleyways, *etc.* Dark corners where rubbish may accumulate are eliminated. The probability of incendiarism and of intruders secreting themselves in the theater is lessened. In case of blackout or electric current failure, a white-washed or painted exitway is safer than one unpainted. Whitewash is an excellent fire retardant.

In an emergency, people need leadership. Without leadership, confusion and panic may occur. Most theaters have a well organized staff. The staffs are, however, being drilled more intensively than ever before in the handling of emergencies. The handling of every contingency that can reasonably be anticipated is being rehearsed with the full theater staff coöperating.

There can be no standard or uniform procedure, as much depends upon the construction and layout of the particular theater. The manager, in each case, is called upon to exercise his ingenuity in devising a routine for his particular house. As many employes as possible should obtain the benefits of an air raid warden's course.

We in the theater business know by experience a great deal about handling people and about crowd psychology. Studies have been made in England of the reaction of persons in air raid shelters to fear and shock. Practical psychologists have classified the types of reaction and have given the remedies. For example, some persons become hysterical, some freeze in place, some can not possibly remain seated, and each must be handled differently to avoid precipitating panic. Further study should be made of this important and interesting subject to the great advantage of the industry. This type of information might be made available to theater staffs to assist them in handling emergencies.

Theater management has a definite moral and legal duty to notify the audience immediately upon the occurrence of an air raid alarm. Physicians, air raid wardens, nurses, and others in the theater have duties elsewhere and must be given opportunity to leave the theater.

The house lights should be turned on, and notice should be given by the responsible head of the theater on duty at the time. He should recommend that the audience remain seated and avoid the greater danger of the streets. The show that has been momentarily interrupted should then go on. The engineer can assist in the design and layout of public-address or other systems for giving prompt and definite notice to the audience.

A theater presents a comparatively simple black-out problem, for it has few windows and doors. The principal problem is the main entrance. Here, by using subdued lighting near the entrance, little light should reach the street. Here we believe the lighting engineers in this Society can be of assistance in establishing standards for the type, arrangement, and color of lamps and the degree of illumination.

Fire escapes and alleyways should be sufficiently illuminated to

provide a safe means of exit. The Society may be helpful in finding or designing an acceptable outside exit light and establishing acceptable standards of illumination.

There should be provided an emergency lighting system supplied by batteries. Shortages and priorities rule out the internal combustion engine as a source of current supply. Each theater is a special lighting problem, and we have the situation today of each manager working out a lighting system for his theater as best he may. There is much help that the lighting engineer can give in selecting and standardizing equipment.

Luminous materials, including paints, are being advocated for marking exits and for parts of ushers uniforms. Some of these are permanently luminous; others require periodic exposure to light; others require ultraviolet light to activate them. None of them should be adopted before testing under actual conditions. Here are opportunities for the Society to establish standards for these materials.

The fire-protection engineer has given much intelligent study to methods of extinguishing incendiary bombs, and certain definite standards for materials and equipment have been established. In spite of this there is a host of salesmen attempting to foist upon the public trick extinguishers, powders, *etc.* We must remember that the problem is not so much to extinguish the bomb itself, but to control and extinguish the fire started by the bomb.

Sabotage has, in the opinion of qualified persons, evidenced itself very little as yet. We know of none attempted in theaters. The operator of any property should, however, be informed on this important subject. The forms aimed at theaters might be:

(*1*) Incendiarism, causing fires.
(*2*) The planting of bombs in public places.
(*3*) Creating disturbances or alarm in order to instill fear and make people jittery.
(*4*) Miscellaneous damage.

Enemy agents are provided with ingenious and effective devices for starting incendiary fires. The devices may be designed to operate several hours after having been planted. There is little personal danger in handling or extinguishing devices of this type. A clean theater and frequent inspections are the best preventives.

Should a bomb be discovered it should not be disturbed, for it may contain a mechanism designed to set it off if it is lifted or moved.

Nor should the bomb be plunged in water. Bombs may be designed to operate upon being submerged in water. Inasmuch as the bomb must not be disturbed, the theater must be emptied at once upon discovery of it, and the authorities should be notified immediately.

Each manager should quietly discuss the matter of sabotage and the handling of bombs with the appointed authorities, whether they be the bomb squad, the police, the fire department, or the F. B. I. Where there is no regularly appointed authority an explosives expert may be available.

Sandbags, felt mattresses, or other protective devices should be used only by experts, for attempting to confine the explosion may only intensify it.

The primary concern of the theater operator is the preservation of human life. He is interested only secondarily in the preservation of his property.

If the manager suspects that any disturbances in the theater may be planned sabotage, he should inform the local police or the F. B. I., avoiding, however, any liability for false arrest, defamation of character, *etc.* Sabotage may take the form of damage to the theater or equipment, such as motion picture machines, sound equipment, or switchboards.

No one should be admitted to remote portions of the theater, particularly the stage, dressing rooms, and basement. A thorough search for hidden intruders should be made upon closing. Doors should be provided with modern locks. Access to the theater by means of fire escapes and roof should be prevented. Night crews should report any unusual occurrences. Police should try doors on their night rounds.

Inasmuch as the civilian defense publications relating to theaters have not discussed sabotage we have covered the subject here in some detail.

In conclusion, this is no time for hysteria nor is it a time to blind ourselves to grim realities, whatever they may be. We in the motion picture industry have proved many times in the past our full sense of responsibility to the community and we shall continue to do so with renewed energy and determination.

TECHNICAL PROGRESS IN THE MOTION PICTURE INDUSTRY OF THE SOVIET UNION*

G. L. IRSKY**

Summary.—*Ten years ago the young Soviet motion picture industry was merely in the embryonic stage and had no basic technical facilities to cope with the problems inherent in the new industry.*

At present there are factories in the Soviet Union producing equipment, films, and accessories for the motion picture studios and theaters.

In recent years many studios have been rebuilt and adapted for sound motion pictures and a number of technical problems connected with it were solved. As for the near future, there are improvements to be made in the quality of raw films as well as further improvement in the printing and developing technic.

Industry in its entirety is young in the Soviet Union, but the motion picture industry is the youngest of all industrial branches. We have not yet, indeed, reached the high standards of the American motion picture technic. However, if we consider the accomplishments of the last ten years, the significant progress of this young industry will become evident.

With the rapid development of the sound motion picture it became evident to us ten years ago that satisfactory results could hardly be expected with what means we possessed at that time. Our studios were not adapted for producing sound-films, nor were the accoustics of our theaters adequate to meet the requirements of the sound picture. Furthermore, our laboratories did not have the necessary developing and printing equipment so that most of this work was done by hand.

The difficulties in making sound pictures were further aggravated by the lack of enterprises to manufacture noiseless cameras, special types of microphones, amplifiers, and sound-recording equipment. The distribution of the available sound pictures was limited by the shortage in the necessary projection apparatus.

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* Presented at the 1942 Spring Meeting at Hollywood, Calif.

** Chief Engineer of the Motion Picture Industry of the Soviet Union.

We had only one plant producing films, and this one could not guarantee the quality of its product since the technological processes used there were old and outdated. Furthermore, the facilities of the plant were very inadequate to meet the demand for positive and negative films.

We lacked also the necessary experience and personnel. The average age of our motion picture engineers, at the present time, is between 24 and 30 years. Hence, ten years ago there were no people who could undertake the solution of the multitudinous problems involved in the new development.

For the elimination of all the above-mentioned difficulties, time was required. As yet we have not overcome them all. However, the work done has laid the foundation for a speedy development of our motion picture industry. Unfortunately, the war has to some extent impeded the conversion of a whole series of very vital and already finished experiments into practical use. But I emphasize "to some extent," since our motion picture industry as well as the entire industrial structure of the Soviet Union is rapidly overcoming the effects of destruction brought about by our enemy's temporary successes, and with the enthusiastic and self-sacrificing assistance of our people, continues to progress.

In this report I shall endeavor to describe the basic factors characterizing the progress of our motion picture industry. In the past ten years, we have built a number of factories in Moscow, Leningrad, and other cities for the manufacture of various kinds of motion picture equipment. Our inventors and designers have built a few new types of newsreel cameras. These cameras were manufactured by us in our factories, and the results proved to be most satisfactory under various operating conditions. It is well to mention that among these newsreel cameras the one with the inside magazine has received high praise from the cameramen.

Another camera noteworthy is one used in trick cinematography, with a very stable mechanism assuring accurate positioning of the picture frame. A few groups of such cameras have been built and have given satisfactory results. In 1940 our factories manufactured the first types of noiseless sound cameras.

A few years ago our factories began to manufacture automatic developing machines, and as a result, most of our studios switched from hand developing to machine procedure. Our factories make several types of developing equipment: some are small machines for

studio laboratories and others are of considerable capacity for establishments supplying prints to the motion picture theaters.

In our country we aim to increase the development of national culture, which naturally is reflected in the cinematographic art. More than eighty languages are spoken by the vast populace of the Soviet Union. A great number do not understand the Russian language. These films must be accessible to the entire population, and therefore eighty per cent of our pictures are re-recorded into an average number of 30 to 40 national languages by means of dubbing.

The national actors are invited to view the pictures, then they repeat the words in their own languages before the microphone. Difficulties were encountered in this phase of the work, for it is not an easy task to control the time elements involved in synchronizing the voice with the allotted sound-track.

We have designed special equipment for controlling the synchronism of the dubbed voice and the action on the screen. We have made great progress in this branch of cinematography, and are proud to have overcome the many obstacles in our way.

There are at the present time, in the Soviet Union, about 40,000 motion picture installations equipped with domestic projection machines. Our movie theaters are of various seating capacities and are, therefore, furnished with various types of sound projection equipment. Some are stationary installations equipped with high-intensity arc lamps; others are medium-size installations, and some equipment is of the portable 35-mm and 16-mm types mounted on vehicles.

For the past few years, our factories have been making sound-recording equipment designed by the Russian Professors A. Shorin and P. Tager. Four years ago we started also to manufacture the RCA sound-recording systems. We have had some difficulties in making a precision-type sound-recording galvanometer. Some of the difficulties have been eliminated by our own efforts, and we hope to overcome others with the assistance of the RCA.

The domestic supply of motion picture equipment and films is insufficient to meet the demand, so that in addition to the foreign purchases of equipment, most of it coming from the United States, we are endeavoring to increase our own production.

(*1*) *Improvements in Sound Recording.*—Our industry set-up is quite different from what you have over here, with the concentration of the majority of the studios in Hollywood. Under the Soviet

Union conditions, where great attention is being paid to the cultural requirements of the various nationalities of our land, we must have separate studios in all the national republics of the USSR. Most of these sixteen republics already have such studios. The servicing of these studios, spread over great distances, is naturally difficult. This, however, does not interfere with their development. On the contrary, due to communication difficulties they have become more independent. At the same time the experiences of each studio are shared by all the others.

We were greatly concerned with the accoustical improvement of our studios. We have achieved optimum reverberation in most of our leading studios, such as in the Mosfilm, Lenfilm, Detfilm, and Georgian studios. The new Mosfilm studio meets all the requirements necessary for the production of first-rate sound recordings.

Considerable work has been done in sound-proofing our studios from external noises and vibration.

In 1938 we started to produce the RCA equipment *PM-38* and to date a few dozen units have been made. As mentioned heretofore, we had some difficulties with the RCA mirror galvanometers, which were also experienced previously in the Hollywood studios. In order to eliminate these difficulties a noise-reduction bilateral shutter is being substituted for the three-angle mask, and to improve the speech recording, which came out previously with considerable amplitude distortion, a compressor was put into use.

To obtain greater amplifier stability in sound recording and reproduction as well as to improve the frequency response, and reduce interference and distortion, we are using to a great extent the principle of feed-back amplification.

We are not satisfied altogether, as yet, with the quality of our sound recordings. The reasons for this are to be found in the low standard of our sound-recording films and in the shortcomings of the galvanometers, essentially in their amplitude characteristics.

So far as the galvanometers are concerned, we have indeed made considerable improvements. We are still experiencing production difficulties and the amount of rejections is quite high. We hope to solve this problem too. In case of failure, we shall be compelled to adopt a new modulator made by Professor Shorin, which is easy to produce and assures a high quality of sound recording, but which will necessitate considerable changes in the technological processes.

Recently we have paid considerable attention to the problems of

re-recording and multi-channel recording, in improving the electro-acoustical characteristics of the sound-recording channels. We have begun the production of new microphones, but the quantities are yet insufficient to meet the demand. A limited quantity of testing and measuring equipment produced by us has enabled us to standardize the sound-recording procedures and controls.

The results of these improvements made can readily be seen in such pictures as *Moscow Laughs*, *Circus*, *A Musical Story* and *Anton Ivanovitch*.

(*2*) *Improvements in the Film.*—The quality of the raw film is very essential in determining the final sound and picture quality. As mentioned before, we had one old plant for manufacturing raw films. While we were successful in obtaining satisfactory results under semi-laboratory conditions, and a limited supply of good-quality film, the same could not apply after we went into mass production of film. However, before mass production of film could be started, considerable research work had to be done on the development of the new technological processes. A number of very interesting processes have been developed, including new processes of ripening and washing the emulsions, drying the films, making multi-layer emulsions, *etc.*

These new processes have not yet been applied under production conditions, but will be applied in the new plant recently built. This new plant was completed during the war, and is now producing films for civilian consumption as well as for the army. After the war we plan to produce films in sufficient quantities to cover our demands.

(*3*) *Improvements in Printing and Developing.*—The improvements in the printing and developing processes could not be made while these processes were manual. The introduction of automatic mechanical equipment resulted in some improvement and we hope still further to improve this situation in the very near future. We have already taken steps in this direction.

A year ago we made the first line of printing machines, and finished a machine for non-slip sound-track printing based upon RCA specifications. We had some difficulties with this machine, since the non-slip printing mechanism did not have the necessary operational stability.

We have developed standard procedures for printing and developing and have produced some control and test equipment. The quantity of this equipment is far from meeting our demands so that

we have had to purchase and consider purchasing more printing machines in the United States.

Last year we were trying to improve the developing process. Some experimental work has recently been completed on the effect of turbulation of developers, and we hope that this and other research will enable us in the near future to improve considerably our technics of printing and developing.

(*4*) *Color-Films.*—Up to recently our color-films were limited to two-color processes. We have well equipped laboratories at the Moscow and Kiev studios for two-color films. Some of our color productions, as, for instance, *Grunia Kornakova*, *The Fair of Sorochino*, and others, have been very well received.

In view of the fact that the two-color films made it impossible to utilize fully the color potentialities, a few years ago we started experiments with three-color processes. The main work in this connection is carried on in the Lenfilm and Mosfilm studios and by the Scientific Research Institute.

Due to lack of experience, we have encountered a number of difficulties, especially in carrying over the experimental work from the laboratory to the studio. We are working on several methods in order to find the best one.

The best results have so far been obtained with a special camera using three-color films. Eighty per cent of our cartoons are made in color, and we believe that the color cartoon is the first step in the further development of our color pictures.

It is our opinion from our limited experience in the production of color-films, and in spite of satisfactory results obtained by using three films, this method will not be acceptable on account of the bulkiness of the camera and the complexity of the printing and developing processes.

We believe that real progress in color pictures will be attained only after means are devised whereby color pictures may be made with the standard camera, using a single film, and after developing and printing procedures are simplified. This is more easily said then done, and we well realize the difficulties that will be encountered. We shall find it necessary to devise new methods for developing and printing color-films and to rebuild some departments of the film manufacturing factories. We will have to solve our technical problems more rapidly than heretofore and we intend to obtain the assis-

tance of American specialists in the field, as we have done in regard to sound recording.

(5) *Stereo-Motion Pictures.*—In the Soviet Union, as in many other countries, we have experimented with the so-called "three-dimensional movies." We should like to see our movies as representing real life, and are not satisfied with the flat two-dimensional scenes. After experimenting with all the known methods of screen viewing with special eyeglasses, as, for instance, the anaglyph method, the polarizing method, eyeglasses with shutters, *etc.*, we have come to the conclusion that none of the methods based upon the use of eyeglasses could have any practical application. We would rather equip our theaters than our audiences.

The inventor, Mr. S. Ivanov, has built a screen consisting of two surfaces: one surface (rear) is a standard motion picture screen, but the other (front) consists of a frame with metal wires spreading fanwise from the lower part of the screen. The picture is taken with a standard camera equipped with a device that divides the image into two, so that an object is photographed from two separate points, just as each of our eyes records a separate and different view of an object. During the projection of the film each eye of the spectator sees a separate image, and a depth effect is obtained.

A special motion picture theater has been built in Moscow for showing stereoscopic films without eyeglasses. The impression upon the audience is so strong that the spectators forget they are in a theater. Imagine "seeing" pigeons flying about almost in the middle of the hall, or cigarette smoke spreading over one's head!

We attach considerable importance to stereoscopic motion pictures without the use of eyeglasses. The work done thus far is only the beginning, and we believe that Mr. Ivanov's method has a bright future. However, the work is only in the experimental stage and requires some development to simplify the screen, increase the brilliancy, *etc.* We cherish the idea of combining the stereoscopic images on the screen with stereophonic sound, based upon the developments of RCA and Bell Telephone Laboratories.

(6) *Improvements in Projection.*—Ten years ago we had about 20,000 installations, of which only 2 or 3 per cent were sound; but now we have close to 40,000 motion picture installations and 80 per cent are sound. They are of many varieties. In addition to regular motion picture theaters we have also a tremendous number of portable equipments.

We pay considerable attention to the cultural requirements of our villages. Whatever is done in our cities is immediately carried out to our villages. Many of the latter are located far from railroad lines so that the equipment together with the films must be transported on carts, trucks, and special automobiles. For some localities having no electricity, power equipment must be transported.

Each village and collective farm desires its own motion picture installation, and it is quite difficult to satisfy the demand for equipment and films. In order to meet the demand we have a great number of portable equipments for transporting both equipment and films from place to place.

There are some places in the Soviet Union, for example, the Caucasian Mountains, which during certain periods (in winter and early spring) are not accessible either by horses or automobile. To such places the men and equipment are carried in planes.

Our Red Army likes the movies, too. For them we provide special vehicles equipped with motion picture installations, radios, microphones, and phonographs. These vehicles also carry special equipment for showing pictures in the military camps during the daytime without the need for darkened places.

The average number of prints made from each new film is from 500 to 1000, and often this amount is not sufficient.

Such a great requirement for prints has made it necessary to adopt measures for prolonging the life of the films. We have developed special treatments for the care of prints, making it possible to increase their runs from eight to ten times.

The amplifying and acoustical equipment of our theaters previously was of obsolete types which made it difficult to obtain high-quality reproduction. Two years ago we designed some modern amplifiers which are now being installed in the theaters.

One of these amplifiers is of particular interest: Professor P. Timofeev of Moscow and Engineer B. Kubetzki of Leningrad have designed a secondary-emission phototube multiplier, which has made possible the building of a very compact amplifier. The electronic beam of Professor Timofeev's phototube is focused electrostatically. Its sensitivity is about 500 milliamperes per lumen and the noise level is around minus 55 to 60 db; it has an absolutely flat frequency response curve for the audio-frequency range; total voltage applied, 500 volts.

This photo-multiplier is substituted for the phototube and pre-

amplifier. Depending upon the size of the theater, a power output stage is connected to it, usually consisting of two tubes (push-pull circuit). It is a light, compact amplifier easy to service.

Another important development consists of a high-pressure 120-volt a-c or d-c gas lamp having a rating of 250 to 300 watts. The gas pressure in operation is 80 to 100 atmospheres. The brilliancy of this lamp is equivalent to a 3-kw arc lamp. Its average life is 200 hours.

We have begun also to produce new loud speakers with permanent magnets, selenic rectifiers, motion picture screens, *etc.*

CONCLUSION

In addition to the problems already mentioned, on which we have been working for the past few years, there are many more to solve in the very near future. The major and immediate problems to be solved by our institutes, laboratories, and factories are quality improvements in sound recording and further development of color and stereoscopic pictures. We hope that you in American industry will continue to help us as you have done in the past. We are confident that, with the growing number of experienced personnel, and the help of the now powerful Soviet Union industry, we shall speedily overcome these problems.

I feel that we are justified in such expectations in the light of the achievements accomplished during the recent years by our people.

THE DEVELOPMENT OF THE SOUND-FILM*

JOHN E. ABBOTT**

Summary.—*With the appearance of the part-talking film "The Jazz Singer" in 1927 a new era began. Talking films had been introduced before, but not until then had the engineers solved the problem of amplifying as well as of recording and reproducing sound. As often, technical invention preceded creative use and at first the new machines were used clumsily. Yet it is well to recall the character of certain primitive talkies in order to understand what the elements were which stirred the wonderment and curiosity of the public, and it is the only effective way of appreciating the speed and ingenuity with which this apparent retrogression in film-making was overcome during the next few years.*

The profound interdependence of film technique and the technics of film is nowhere seen so clearly as in those first years of the transition to sound—1927 to 1932. Silent pictures had developed a method of telling a story all their own: by the end of the silent era, the film medium had been enriched by the work of creative directors, had been made a fluent instrument for the expression, through pantomime and suggestion, of even the most complicated emotions and ideas. Only with the utmost reluctance did the lovers of cinema surrender to that blasting, squalling—but terribly popular—new plaything, the talkies. To them it seemed that motion pictures, in gaining a voice, had lost a soul.

And actually it had lost almost everything that was at the root of cinematic creation. Freedom, speed, the penetrating close-up, the broad, revealing pan and all outdoors simply disappeared overnight as the microphone overwhelmed the studios in the great onrush of sound. The inclination, of course, is to say that the bulky sound camera, the tons of unportable sound equipment, the imposing problems of acoustics were directly responsible for this change. But that would be an oversimplification in view of the fact that producers, faced with the immediate necessity for getting new material to rush

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** Museum of Modern Art Film Library, New York, N. Y.

before the sound cameras, turned to what was nearest and most adaptable—and that happened to be the stage play. Esthetically, the motion picture since 1929 had too often been struggling to break loose from that unfortunate grafting of the theater upon the film.

It became, then, a question of film technician and film creator working side by side to thrust aside the confinements of sound technic. Early microphones could never be set more than a few feet away from an actor. Thus, while sound engineers worked to broaden the range, Ernst Lubitsch in *The Love Parade* (1929) interpolated long silent pantomime sequences—a tentative groping back to the movement of silent technique. Or Von Sternberg in *Morocco* (1930) pared dialog down to laconic meaningful phrases spoken in the near shots, while a vague atmospheric wild track of sound and music accompanied the camera as it wandered through the shadowy back streets of an exotic city.

The real release of the camera came, however, in the flood of musicals that danced across the screen from 1929 to 1933. In them, the creative imaginations of men like Lubitsch, Tuttle, Mamoulian, and Busby Berkeley were freed of the conventions of plot narration that had already become deeply intrenched. Just as abroad the experimentation was carried on largely in the musical films of Clair and Thiele, so here in America the new technics developed while Jeanette MacDonald sang to Maurice Chevalier. Self-conscious these films were in the extreme and, seeing them again, one is struck by their unevenness, by the banalities that persisted on either side of the experimental sequence. But there was the close coördination of music to visuals in the train sequence in *Monte Carlo* (1930), a happy return to rhythmical cutting in *This Is the Night* (1932) and the songs from *Love Me Tonight* (1932), a freer dialog in the rimed couplets of Lubitsch's *One Hour with You* (1931) and in the fast comedies of the Marx Brothers.

Films returned to their outdoor settings with *In Old Arizona* (1929), "filmed 100% talking—100% outdoors." This time the victory was the technicians' who had built an apparatus that could be carried beyond the walls of a studio, for the actual problems of shooting sound outdoors are greater than those on a studio set. Almost immediately the old Westerns were back and most of the old Western stars, including even Tom Mix. Their action was somewhat impeded by the new, stilted dialog, true—but then, in what film was that not so?

Disillusion, despair, cynicism, a brutal disregard for authority

characterized the close of the 'Twenties—themes that found expression in the theater in a series of hard-written newspaper and underworld plays. Hollywood, hungrily snatching up almost any play that lasted beyond opening night, could hardly ignore the success of *Broadway* or *The Front Page*. Written with fury and fire, with references as timely as newspaper headlines, these plays talked about things close to the life of the moment with a vivid, compelling realism.

And, somehow, so did the pictures made from them. One still remembers Edward G. Robinson in *Five Star Final* (1931), the hard-as-nails, unscrupulous, in-the-know managing editor of a yellow sheet, or Lee Tracy in *The Front Page* (1931), cynical, glib, wise. They knew what the score was, and talked about it in the argot. A new realism, a realism which we now recognize, however, as being rather mannered and contrived out of reality, was suddenly thrust upon the screen amidst all the polite drawing-room comedies and boudoir melodramas that had clogged it from the moment the screen began to speak. In accents we could all recognize we were told things that we could understand—even wanted to hear. For a puzzled, worried people that had seen its savings vanish as banks closed and stocks crashed, it was a relief to be told that there was corruption in high places, that the blame was not our own.

The connection between the underworld and the fourth estate, hinted at in *The Front Page*, was developed further in the great cycle of gangster films that followed on the success of *Little Caesar* (1930). There had been isolated gangster films before, but the success of that picture and its even more sensational successor, *The Public Enemy* (1931) cleared the way back to the tempo of the silent films. After ten years the dialog in these pictures still seems clipped and racy, the cutting fast, nervous.

A social consciousness not often associated with Hollywood stole into pictures. No matter what the actual story might be—and often in spite of the story—it was there, forthright and fearless in *I Am a Fugitive from a Chain Gang* (1932), sugar-coated with a happy ending per NRA in *Wild Boys of the Road* (1933). The technics of reality were explored in those films, the technics that were to re-emerge, after all the permutations through the middle thirties, in such stark social statements as *The Grapes of Wrath*, and the industry's present war production program.

Abroad, the Russian film seems never to have quite overcome the

exigencies of sound recording. The great directors of silent days, Eisenstein and Pudovkin, while still prolific with theories, have actually produced few films, and none which has equalled their earlier masterpieces. An occasional film from France has reminded us of that country's contribution to the screen—taste and refinement, perception for detail if not passion for rousing action.

In Germany, Nazi doctrines dominate the entire film industry and the resulting pictures have been either monotonous variations on the *Zwei Herzen* theme, or instruments of political propaganda. *The Triumph of the Will* and the celebrated German Campaign films, interesting technically, will certainly provide material for post-war psychologists investigating the influence of film on the mass mind.

England's motion picture industry has constantly been striving to become as similar to the American as possible and in the early thirties began borrowing Hollywood actors and technicians to further the illusion. How successful it has been may be measured by the extent to which American producers have called English actors and technicians to Hollywood.

Perhaps more important for today, though, is the development in England of a documentary movement. Since the very first years of sound, under the leadership of John Grierson, a closely knit group of film makers has been experimenting with, and has finally produced, a technique for the dramatic presentation of reality. Film theoreticians and film technicians in one, these men have come forward in the last three years through their magnificent work filming the British war effort.

Today the movement goes on, film creator and film technician collaborating more closely than ever before. One has only to think of *Citizen Kane*, of Toland's photography for Welles' script; the improvements in lenses, the advances in recording, processing, effects—all tending to a more fluent, more expressive medium. The importance of that medium is clear enough today. Films are playing a strategic part in all branches of the American war effort, from civilian morale to Army training. Films for diversion as well as films for defense have their significance.

The long-range estimation of that significance, however, must come from future study by film experts. The staff of the Museum of Modern Art Film Library which collects, examines, and preserves what it considers to be the significant pictures, has discovered from direct experience how completely ten years can change the entire

meaning of a film, while styles of acting and of dress can become outmoded in as little as three. What at the moment seems right and just—esthetically, socially, politically, no matter—becomes, with some perspective, the harshest kind of comment on ourselves. We have learned caution.

The film is a thing of today, rising out of today and appreciated by today's standards. But it is also an art that freezes today for all time. Examination of past films reveals advances and innovations in technics, advances that have come about in this country through experiments within the major studios as well as independently in the documentaries. But that examination is even more revealing of advances and innovations in ourselves and our conception of the world in which we live. Through fifteen hard and troubled years, the film has gained a voice. It will tell us much about those years, some day.

EDWIN S. PORTER*

Last Fall, by recommendation of the Board of Governors of the Society, and by vote of the membership at the 1941 Fall Convention of New York, the name of Edwin S. Porter was added to the Honor Roll of the Society, and appears on the back cover of each issue of the Journal. The following article is a contribution to the Report of the Historical Committee prepared by J. E. Abbott, Chairman, and Richard Griffith, member of the Committee.

Contemplation of the history of motion pictures reveals few more significant figures than Edwin S. Porter and none about whom less is known or has been written. Yet he was a pioneer, a trail-blazer who left an imperishable footprint on the film. Both inventor and artist, he was also a practical man of business and an adventurer with vision. He invented the first portable projection machine out of which evolved a projector that is universally used today, the Simplex.

More, perhaps, than that, he was the first to tell a story on the screen. The importance of that is lost sight of today because we take for granted that the film has always spun a tale. We remember the fables were crude at first, but scarcely any one of us realizes that once upon a time there was no such thing as the rudiments of narration on the film, even though the film itself existed and reflected action, life, upon the screen. Prize fights, snatches of acrobatics, butterfly dances, and kissing duets comprised all the screen apparently had to say. Porter, then learning to be a cameraman in the Kinetograph Department of Thomas A. Edison's laboratory, photographed many such episodes. He and his chief, James H. White, thought of something better and longer. It would achieve the then unprecedented length of five hundred feet and would be called *The Life of an American Fireman.*

Quoting Terry Ramsaye's "A Million and One Nights," the description follows: "(It) portrayed the routine duties of a fire chief. The audience was taken the rounds of the fire house and inspection with the chief. Then cutting in with an inspirational beginning of a new technique, came a scene showing a simple cottage, with a baby asleep in a crib, by a window with curtains fluttering close to the burning gas jet turned low. The curtains flicked into the flame and

* Presented at the 1942 Spring Meeting at Hollywood, Calif.

the fire crept up the window and licked along the window casings. The mother awakened in the smoke-filled room. Then the picture cut back to the fire house where the alarm tapped out a signal. The firemen leaped to action, sliding down the brass poles from their dormitory into the engine house. The horses were hooked up in a flash, and with smoke and sparks flying the outfit thundered down the street. Then the long arm of John R. Coincidence, the perennial first-aid of scenario writers ever since, reached out and into the first motion picture drama. It was the fire chief's house. The picture cut back to the baby's crib again, back to the frenzied mother in the swirling smoke. Then again to the rushing fire engine.

"Mark this: it was the grand staple situation of dire peril, with relief on the way, the formula that has made Griffith famous, or that Griffith has made famous, as you choose to view it. It was and is yet the greatest screen situation, of unfailing power . . . In this ancient drama, *The Life of an American Fireman*, the chief arrived at last and leaping down, rushed into the fire, emerging with his wife and child in his arms. Saved at last! . . . All this was crudely done measured in the light of our day. It was a gripping masterpiece then. It swept the motion picture industry."

Shortly afterward, in 1903, Porter produced a far more ambitious film of greater historical importance. It was called *The Great Train Robbery* and is now a treasured item in the archives of film libraries fortunate enough to own a print.

His next move was to make films of social import, and *The Ex-convict* and *The Kleptomaniac* were protests against the injustices of the world. These were well received and proved that the screen could appeal to the intellect as well as to the emotions.

In 1906 he furthered the fantasy of films with his imaginative creation, *The Dream of a Rarebit Fiend*, in which he used many trick devices.

Finally Porter quit the Edison Company and formed his own company, the Rex. The imprint of his talent upon films of this organization made it one of the most important in the industry for the next five years.

Then he went into partnership with Adolph Zukor and Daniel Frohman in the formation of the Famous Players Company, directing for the new organization the first six-reel film, *The Prisoner of Zenda*. At that time he did just about everything except acting: all the camera work, script writing, and directing being done by himself.

With Famous Players he made many of the greatest pictures of the

day, including *Tess of the Storm Country*, with Mary Pickford. Budgeted at only $13,000 it grossed more than a million dollars—more, in proportion to its investment, than any film ever made. Later, Porter took a company of players to Rome to make *The Eternal City*. Released in 1915, this was his last film.

He retired at the age of 43, wealthy and satisfied to take life easily. But inactivity bored him, and in 1917 he became president of the Simplex Projector Company, supplying most of the theaters with his machines.

Again he retired, but after the crash of 1929 he returned to the mechanical side of the industry. His hobby, before his death in 1941, was the designing of innovations for still cameras and projectors. Ironically, he had been forgotten by many of the leaders in Hollywood, and, in fact, by the majority of the industry to the foundation and progress of which he had so richly given of a talent and energy that could only have belonged to a pioneer.

To describe each and every one of Porter's inventions and innovations is next to impossible; not alone because they were numerous, but due to the fact that his experiments in camera work were made many years ago and were immediately assimilated by the industry and are current today.

Before the turn of the century he photographed against the sun when he backlighted a yacht race, thereby achieving a new effect which no one had attempted before but which was instantly adopted by every cameraman and, through various stages of elaboration, is now a fundamental trick of every photographer.

He first introduced the close-up in *The Great Train Robbery*. It was the sensational punch of that revolutionary film. A desperado pointed a revolver into the eye of the audience.

Double exposure, too, made its first appearance in the same film, though the example of it is known only to a comparatively few students of the film and is not double exposure as it became later. Through the open door of a railroad car is seen the moving landscape. The car was faked for the occasion and was stationary, and the landscape was not a panorama of painted scenery but was a moving photograph superimposed upon the space left by the open door of the car. But indubitably it was double exposure. When all is said, however, and the whole that might be said of Porter never will come to light, his perfection of the portable projector, linked with its wide use today, must ever stand as the perfect signature to his career.

CONCERNING PHOTOGRAPHY AS AN ART IN AMERICA*

LLOYD E. VARDEN**

Summary.—*Photography has played a major role in the development of art interest in America chiefly because of its mass appeal and ease of execution. The early growth of art photography was slow but with the formation of an increasing number of camera clubs, and finally several national groups, the movement was fastly accelerated. With the coming of the miniature camera and the successful organization of the Photographic Society of America the continual progress of photo-pictorialism was assured.*

Photography, both motion picture and still, as an esthetic art has had a significant influence on the habits and thinking of American people. Back in 1912 Sadakichi Hartmann, writing in *Camera Work*, had occasion to note that motion pictures of the day, in spite of their questionable artistic quality, had a strong appeal for the mass population. To Hartmann, the fact that people would pay to see motion pictures in preference to attending free art galleries was somewhat disconcerting.

As the esthetic refinement of motion pictures progressed, so did the taste and art critique of the theater-going public progress. This ability to judge the esthetic quality of motion pictures developed so rapidly that producers were taxed to the limit of their ingenuity in keeping a short pace ahead of audiences.

That motion pictures have had a great influence on the art standards of American people is not to be doubted. The fact is recognized and well known. On the other hand, the part which still photography has contributed in raising the level of our art appreciation has not been so familiar to most of us. For this reason I should like to present a brief picture of the development of pictorial photography in America and in addition, say a few things about its present status.

Struggle of Photography to Be Recognized as an Art.—Photography

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began as an art medium. As stated by Edward Weston in the Encyclopedia Britannica, "Photography was brought into being by artists and would-be artists in search of a new pictorial method." Unfortunately, as a new art method, photography was judged on the basis of its resemblance to existing methods. For many years the progress in pictorial photography was hampered by the fanatical idea that a distinctly new approach to artistic expression was untenable. Even today we find that photography is not recognized in all quarters as a definite form of art; but certainly the situation is vastly improved.

The first man to begin a new school of thought in pictorial photography, but not necessarily the first to conceive the idea, was the American, Alfred Stieglitz. Soon after the turn of the century, Stieglitz formed a group called the Photo-Secession, dedicated to the establishment of photography as an independent art. As a part of their work two publications were issued—*Camera Notes* and *Camera Work*. The latter was an outstandingly fine series of quarterly magazines containing selected articles and pictorial photographic reproductions on thin Chinese rice paper. The Photo-Secession held salons in New York City and comments which can be found in newspapers of the day show that the exhibits gained considerable attention. However, by the time the last issue of *Camera Work* was published in 1917, pictorial photography had not as yet gained a very notorious position in America.

Beginning of the Photographic Society of America.—Shortly after the end of World War I a renewed interest in pictorial photography began and, as a result, a number of camera clubs throughout the country sprang up. These, in addition to the already established clubs, in the mind of Louis F. Bucher seemed to be a sufficient number to propose the organization of an Association of Camera Clubs of America. Mr. Bucher sent letters to several of the clubs inviting them to participate with the Newark Camera Club in the formation of such an association. Twenty-two clubs responded and were enrolled as charter members.

The Association of Camera Clubs of America grew slowly, but at least it held together and went in a forward direction. There were but fifty clubs in the association by 1933, or an increase of two clubs per year since 1919.

Nevertheless, this increase of club membership encouraged the association to consider a change of name in order to permit individual

membership. In December, 1933, the name of the organization became The Photographic Society of America and was defined the year following as " . . . . an organization of individuals, clubs, manufacturers, dealers, and publishers, united for the purpose of promoting photography as an art, a science, a business, and a hobby. Representing no school or -ism, having no hidebound prejudices or fanatical ambitions, it is a common meeting ground for technician, pictorialist, scientist, realist, romanticist, craftsman, business man, and all others who are truly interested in photography."

Independent Organizations.—The Associated Camera Clubs of America was by no means a singular motivating force in the growth of American photographic art. There were several independent organizations, a few of which I shall at least mention, that helped the situation along tremendously. The Pictorial Photographers of America with headquarters in New York City was an early active group. On the West Coast there was the International Photographic Association, founded in 1908 in San Francisco. The Pittsburgh Salon, consisting of leading pictorialists of the country, did much toward creating a high standard of exhibition photography in America. There were many individual camera clubs that fostered various activities, too, which kept a lively interest in pictorial photography in a more provincial way.

Effect of the Miniature Camera.—The future of pictorial photography as an independent art was assured by the introduction of the miniature camera, although at the time this may not have been evident. The miniature camera did two things: (*1*) it appealed strongly to large numbers of people and caused amateur photography to flourish, (*2*) it brought the necessity for accurate and clean photography by virtue of the small-size negative material utilized.

Thus, a few years after 1925, the year when the first 35-mm still cameras came into use in this country, a movement began which continued to gain momentum right up to December 7, 1941. Non-imitating photographic pictorialism became a reality during this period and photography was chosen as a serious hobby by hundreds of thousands of people.

Growth of Exhibitions, Clubs, and Exhibitors.—In the *American Annual of Photography* for 1927 there are 62 camera clubs and amateur photographic societies listed. Of course, there is every likelihood that the number of clubs was actually greater than 62, but nevertheless, the figure is indicative of the fact that there were not many well established clubs at that time.

But as the miniature camera gained in popularity, more and more workers sought the advice of other workers and soon camera club groups were located in nearly every good-sized village in the country. Museums began to take a more vital interest in photography as an art, and since the art galleries were most suitably equipped for hanging exhibitions, we find that photographic salons began to find their way into numerous metropolitan art museums. Some salons were even sponsored by the museums, which, of course, today is a frequent practice.

Camera clubs in America can boast today of 200,000 members. Thousands of other hobbyists and pictorialists who are not members of clubs swell the total of photoart participants to over a quarter of a million at least. Of this large figure there are less than 1000 actually represented in pictorial exhibits each year. Many others make efforts to have their work hung but fail to satisfy any of the judging committees.

The significant thing about the camera club movement and the increased number of exhibitions is the great influence which they have exerted on the interest in art. A photographic salon today may increase the flow of visitors through an art museum by ten times. Moreover, there are thousands of people interested in art now who were introduced to it only through photography. People who knew nothing about artistic principles prior to acquiring photography as a hobby have many times become familiar with nearly all aspects of the subject.

The reason for this increased interest in art is simply that photography appeals to the mass population. Just as motion pictures strongly appealed to the masses, so has photography as a means of pictorial expression. Photography does not require certain dexterity in the use of one's hands, as in painting and drawing. It allows the execution of ideas without trained skill and developed coördination between the eyes and hands. It gives results rapidly and an encouraging feeling of accomplishment that spurs hobbyists to a more profound study of the subject in all its ramifications.

Analysis of a Typical Large International Salon.—The recent Seventh Rochester International Salon of Photography can be taken as a typical example of a modern photographic exhibition. There were exhibitors from 41 states and 6 foreign countries represented. There was a total of 1940 monochrome prints submitted and 504 accepted for hanging. Besides these, there were 114 color prints,

34 of which were hung. The prints ranged in size from 8 × 10 inches, or smaller, to 16 × 20 inches, but by far the majority of prints hung were the 14 × 17-inch ones, with 11 × 14-inch prints coming next with less than half as many. Out of 507 entrants, 242 failed to have any prints accepted, or a little over half the people who sent prints were represented in the exhibit.

It is obvious from these figures that photographic salons are highly patronized. Granted that the salon in question is one of the larger ones held in America, it is nevertheless exemplary of the enthusiasm in the work.

The Present Status of the Photographic Society of America.—The main growth of The Photographic Society of America has been coincident with the rise in the popularity of photography. The individual membership is today in the neighborhood of 2000 with several hundred club members, embracing a total membership of over 20,000. The headquarters offices are now situated at the Franklin Institute in Philadelphia where the PSA Journal is edited and where the library is housed.

The Society is perhaps the most stalwart force behind photographic art in America today. Upon its success will greatly depend the future of photographic pictorialism as a fundamental factor in bringing art to a great mass of people. Although the Society embraces all fields of the science and practice of photography, its greatest contribution has been (and probably will continue to be for sometime) the advancing of photography as an art.

Conclusion.—I have tried to sketch very briefly the rapid growth of photography as an art in America. This growth has had a significant influence on the widespread dissemination of art knowledge and principles of art appreciation. Photography appeals to the masses because it is an art which nearly anyone can execute. The initial interest in photography leads to a desire to learn more about aesthetics as a whole and as a result we today find art galleries and camera clubs working hand-in-hand.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C., at prevailing rates.

American Cinematographer

23 (March, 1942), No. 3

Filter-Factors for Daytime Night-Effects (pp. 106–107) — V. E. Miller

Scattered Light in the Focal Plane (pp. 109, 138–140) — P. C. Smethurst

Wartime Economies by "Pre-Photographing" Scripts (pp. 110, 132) — J. J. Rose

Professional Production in 16-Mm (pp. 111, 128, 130, 132) — J. A. Larson, Jr.

Kodacolor Introduces Negative-Positive Color Stills (pp. 118–119) — W. Stull

Know Your Shutter! (pp. 123, 132–133) — R. Fernstrom

23 (Apr., 1942), No. 4

Animated Cartoon Production Today (pp. 151, 188) — C. Fallberg

Equipment Trucks Streamline Camera Department Operations (pp. 153, 173) — E. B. McGreal

Scattered Light in the Lens-Mount (pp. 154, 186–187) — P. C. Smethurst

Key-Light *vs.* Background Illumination (pp. 155, 185–186) — K. Freund

Camera Equipment for Professional 16-Mm Production (pp. 156–157, 184–185) — J. A. Larson, Jr.

Auricon Sound Camera Makes Bow (pp. 165, 174, 176) — W. Stull

Filters—or Correct Exposure? (p. 166) — A. Lloyd

Shooting for Conservation (pp. 167, 173–174) — O. I. Sprungman

23 (May, 1942), No. 5

Field Hints for Military Cinematographers (pp. 198–199, 226–228) — C. DeVinna

Sound and Editing Equipment for Professional 16-Mm Production (pp. 200, 238) — J. A. Larsen, Jr.

Shooting with the Commandos (pp. 201, 237–238) — H. W. Rignold

Animated Cartoon Production Today. Pt. II, Production Preparation (pp. 202–203, 232–237) — C. Fallberg

Simplified Set-Building for Defense-Film Makers (pp. 210–211, 225–226) — J. Otterson

Testing the Auricon Sound-Camera (pp. 213, 224–225) W. STULL

Educational Screen

21 (March, 1942), No. 3

Motion Pictures—Not for Theaters (pp. 104–106), Pt. 25 A. E. KROWS

21 (Apr., 1942), No. 4

Noteworthy Joint-Session of Midwestern Forum and Department of Visual Instruction, Zone IV (pp. 134–137, 142, 163)

Motion Pictures—Not for Theaters (pp. 138–140), Pt. 36 A. E. KROWS

Experimental Research in Audio-Visual Education (pp. 151, 157) D. GOODMAN

Electronics

15 (March, 1942), No. 3

The Electroplane Camera (pp. 44–47)

Institute of Radio Engineers, Proc.

30 (Apr., 1942), No. 4

Color Television (pp. 162–182), Pt. 1 P. C. GOLDMARK, J. N. DYER, E. R. PIORE, AND J. M. HOLLYWOOD

International Photographer

14 (May, 1942), No. 4

The X-Ray in Motion Pictures (pp. 3–5) J. FAIRBANKS

The Biggest Little Lab. (pp. 9, 23)

International Projectionist

16 (Dec., 1941), No. 12

Physical Characteristics of Film (pp. 7–8) H. SHARP

Control-Track for Better Sound (pp. 10, 12–14)

Color Television in England (p. 15) J. H. BAIRD

17 (Jan., 1942), No. 1

Correct Use of Amplifier Meter Will Assure Better Sound Results (pp. 7–8) L. CHADBOURNE

Progress in Three-Dimensional Films (pp. 10–11) J. A. NORLING

Non-Synch Phonograph Valuable Trouble-Shooting Device (pp. 13, 20)

Dual Photography Matter of Timing (pp. 16–17) H. ANDERSON

Suggested Classification of Carbon Arc Terminology as Applied to Pictures (pp. 18–19, 22) H. G. MACPHERSON

Television in Theaters Long Way Off According to Experts (p. 20)

Lubrication of High Temperature Lighting Devices with Graphite (pp. 21, 23) B. PORTER

17 (Feb., 1942), No. 2

Factors Affecting Sound in Theaters (pp. 7–8) — A. GOODMAN

Advancement of Sound Pictures Grows as Engineers Improve Technique (pp. 12–13, 22–26) — N. LEVINSON

Maintain Projection Room Cleanliness (pp. 14–15) — H. GRANT

Hints on 16-Mm Sound Projection for Defense Film Shows (pp. 16–17) — A. LLOYD

Civilian Defense Orders Shows to Go on Regardless of Raids (p. 19)

Warners Are Testing New Color Film to Compete with Tech. (p. 19)

Motion Picture Herald

147 (May, 2, 1942), No. 5

Library of Congress to Keep Important Films (p. 36)

Better Theaters Section

Reducing Injury and Fire Hazards During Air Raids (pp. 9–10)

Making Sure You Get All Possible Projection Light for Your Money (pp. 22–24, 26), Pt. I — C. E. SHULTZ

Optical Society of America, J.

32 (Apr., 1942), No. 4

On the Performance of Optical Instruments with Coated Lens Systems (pp. 211–213) — J. E. TYLER, R. S. MORSE, AND F. B. JEWETT, JR.

The Effect of Temperature upon the Spectral Sensitivity of Photographic Emulsions (pp. 214–218) — C. H. EVANS

Mercury Sensitization and the Optical and X-Ray Latent Images (pp. 219–223) — A. MAY

An Intensity-Scale Sensitometer That Works at Intensity-Time Levels Used in Practical Photography (pp. 224–229) — W. BORNEMANN AND C. TUTTLE

BOOK REVIEW

The Film Index: A Bibliography, Vol. I, *The Film as Art,* Compiled by Workers of the Writers' Program of the Work Projects Administration in the City of New York. Sponsored by the Honorable Fiorello H. LaGuardia, Mayor of the City of New York, The Museum of Modern Art Film Library, and the H. W. Wilson Company, 1941.

Whatever faults may be found with the first volume of the Film Index are matters of little critical moment, for this bibliography of motion picture literature is the only thing of its kind in existence and is therefore indispensable to every movie worker. The literature of the film is at once so vast and so ephemeral that efforts to make exact research in the history or technic of the art-industry were in the past doomed to defeat and new writing about the motion picture usually perpetuated as many errors as facts. This situation was partly overcome when the Museum of Modern Art Film Library, founded in 1935, began to collect as much motion picture writing as it could find and to make it available to students. Now the second step toward clarification and organization has been taken with the publication of this intricately cross-indexed bibliography. Workers of the New York Writers' project of the W. P. A. spent approximately four years combing books, newspapers, and other periodicals for references to the film: the first fruit of their labor is this 723-page guide to writing on the artistic aspects of film. Two more volumes, "The Film as Industry" and "The Film in Society" are now in work, but the year of their publication has not yet been calculated.

In a volume called "The Film as Art," sections of greatest interest to members of the Society are those under "Technique," including "Surveys of Film Crafts," "Color," "Editing," "Photography," "Production Effects," "Sound." Readers who are motion picture engineers may find much of the material listed here familiar—the Society's JOURNAL is mentioned over and over—but to run through any of the sections is to get a general and impersonal view of the field discussed which corrects the individual expert's natural tendency toward lopsidedness. Incomplete the listings may sometimes be, but they never fail to astound even the veteran specialist with unheard-of writing by unheard-of people on subjects supposedly fully covered by standard writers. As for the remainder of the volume, it is as fascinating and various and full of human attractions—aside from scholarship—as the movies themselves. Even to read aimlessly through the listings, and the brief digests of books and magazine articles which accompany them, is to capture something of the excitement and fervor with which all sorts of people have written about this new, undisciplined, and lively art. Iris Barry's foreword suggests some of the pleasures which the volume supplies, as well as some curious conclusions about the motion picture and motion picture writing:

"It is rather surprising, actually, to observe how early publication on this new topic began: the pioneer W. K. L. Dickson, laboratory assistant to Edison, had a book out in 1859, the very year which is often regarded as the birthdate of the movies. . . . It is hardly news perhaps that the poet Vachel Lindsay was one of the

first to provide critical appreciation of motion pictures, or that Minnie Maddern Fiske was among those who earliest signaled the extraordinary talents of Charlie Chaplin. But it is interesting to discover that the art critic Thomas Craven reviewed Nazimova's *Salome* in 1923, that Joyce Kilmer wrote an obituary tribute to the comedian John Bunny and that Jack London as long ago as 1915 was hailing the motion picture as a means of universal education. . . . The bibliography quite properly aims at being comprehensive rather than selective, but it reveals some interesting facts, such as that Charlie Chaplin has been written about more than any other film personage, with D.W. Griffith close behind him, Mary Pickford and Sergei Eisenstein running third and fourth. Curiously enough, among the twenty-five films which have been most frequently discussed, no less than twelve are foreign ones, though these can have meant little to the general public even if they influenced or imitated Hollywood technique. But the more intellectual and persistent of writers on the film as art have, with few exceptions, obviously tended to write with greater passion and fecundity about exotic and tragic pictures than about domestic and cheerful ones—which suggests a considerable gap between such criticism and the common experience or taste."

As stated earlier, the book is indispensable to anyone who has consistent need to read about the film and its tributary arts and crafts. As for myself, I don't know how I managed to get along before it was published.

RICHARD GRIFFITH

HIGHLIGHTS OF THE HOLLYWOOD CONVENTION

The Convention at Hollywood, recently concluded, would in ordinary peacetimes have been regarded as a very successful convention from all points of view; its success was therefore all the more outstanding in view of the existing war effort and the fact that so many of the technical members of the industry are contributing to this effort.

Both the quality and quantity of presentations on the program were definitely the equal of previous programs, and the engineering branch of the industry may well be congratulated upon the way in which its technical activities are being continued during such a time of stress.

Equally gratifying also was the large attendance at the meetings. Meetings were held each evening during the Convention in order to permit attendance by those who would otherwise be engaged at the studios and laboratories during the daytime. The morning and afternoon sessions, however, were also very well attended. Three of the sessions were held at the General Service Studios, and one at the Carthay Circle Theater. The remaining sessions were held in the Blossom Room of the Hollywood-Roosevelt Hotel.

An innovation of this Convention was omission of the usual Monday morning session, the formal opening of the Convention being the Get-Together Luncheon at Monday noon. This change allowed time for Convention registration, arrival of delegates, and other matters that usually interfere with the conduct of the Monday morning session.

The informal Get-Together Luncheon was attended by approximately 200 persons. Mr. Cecil B. deMille, President of Cecil B. deMille Productions, Inc., producing for Paramount Pictures, Inc., was the principal speaker. Mr. deMille's address was followed by several vocal selections by Miss Martha Mears, courtesy of Paramount Pictures, Inc. Seated at the speakers' table were President Huse, Dr. John G. Frayne, Chairman of the Pacific Coast Section; Mr. E. A. Williford, Past-President of the Society; Mr. deMille; Miss Martha Mears; Mr. Loren L. Ryder, member of the Board; Mr. Alvin Wykoff, pioneer cameraman who collaborated with Mr. deMille in the early days of the industry; and Mr. Arthur C. Downes, Editorial Vice-President of the Society.

The Monday afternoon session, held at the Hotel, included several presentations describing the applications and uses of motion pictures in the U. S. Navy and U. S. Army Forces. Very interesting papers were read on audio-visual aids to Naval training by Wm. Exton, Jr., U. S. N. R,, and on the motion picture camera in the Army Air Forces, by Guy J. Newhard of Wright Field, Dayton, Ohio. Mr. Gregory L. Irsky of the Amtorg Trading Corporation described in considerable detail the technical progress that has been made during recent years in the motion picture industry of the Soviet Union. The session concluded with two papers dealing with developer analysis and continuous replenishment and control of motion picture developing solutions, the first by John G. Stott of the Eastman Kodak Company, and the latter by H. L. Baumbach of the Paramount Studio.

The Monday evening session introduced a new feature into conventions of the Society. Prior to the Convention a special committee of West Coast technicians, following a suggestion previously made by President Huse, made arrangements for a series of nine presentations describing the various vicissitudes through which motion picture film passes from the moment it arrives at the studio as raw film to its final projection as the finished positive in the motion picture theater. The symposium described, step by step, the many technical processes involved, in a series of coördinated papers by authors especially chosen for their qualifications in each field. The symposium covered the Monday evening, Tuesday afternoon, Thursday afternoon, and Thursday evening sessions.

In the Monday afternoon session were scheduled the first three of these papers. Part I dealt with "Cinematography, 1942." The black-and-white phase was presented by John W. Boyle of Universal Pictures, with contributions from Charles G. Clarke and D. B. Clark of 20th Century-Fox Film Corp., and John Arnold of Metro-Goldwyn-Mayer Studios. The second section, dealing with technicolor, was presented by Winton Hoch of the Technicolor.

Part II of the symposium dealt with "Illumination," and was presented by R. G. Linderman of Mole-Richardson Co., C. W. Handley of National Carbon Co., and Alston Rodgers of the General Electric Co. The evening concluded with Part III of the symposium, on the subject of "Laboratory Practices," by J. R. Wilkinson.

The morning of Tuesday, May 5th, was devoted to a visit to the Warner Bros. Laboratories at Burbank under the direction of Fred Gage, Superintendent. In the afternoon the Convention moved to the General Service Studios at which were presented three additional parts of the symposium on the technic of motion picture production. The fourth part, "Production Sound," was presented by H. G. Tasker of Paramount Pictures, Inc.; the fifth, "Scoring and Prescoring," was discussed by Bernard Brown of Universal Pictures; and the sixth, "Re-recording," by L. T. Goldsmith of Warner Brothers. The afternoon was concluded with an interesting presentation on "Motion Pictures: Technology in Art," by L. S. Becker of Warner Brothers.

The Tuesday evening session was held at the M-G-M Studio at Culver City, at which Mr. J. K. Hilliard presented an analysis of the complete sound-recording system in use by the M-G-M Studios, and Theodore Hoffman of M-G-M presented a system of loop synchronization now in use by M-G-M as a means of simply and economically making sound re-takes of unsatisfactory portions of sound records.

The Wednesday morning session, held at the Hotel, was devoted to a number of papers of a general nature, including the report of the Historical Committee by J. E. Abbott, Chairman; "The Historical Development of the Sound-Film from 1927–42," also by Mr. Abbott; and an account of the growth of the photographic art in America by L. E. Varden. Other interesting presentations of the morning included the report of the Theater Engineering Committee, a paper on the production of 16-mm industrial motion pictures by Lloyd Thompson of The Calvin Co., and a discussion of light-scattering by the graininess of photographic emulsions, by Alexander Goetz and F. W. Brown of the California Inst. of Technology.

Wednesday afternoon the members were guests of the Paramount Studio at a demonstration of the equipment and facilities of Television Productions, Inc., under the guidance of E. C. Buddy and K. Landsberg.

The Fifty-First Semi-Annual Banquet and Dance was held in the Blossom Room of the Hollywood-Roosevelt Hotel on the evening of May 6th. The banquet was attended by approximately 250 persons, and seated at the speakers' table were the following officers and guests of the Society: Mr. Emery Huse, President of the Society, and Mrs. Huse; Miss Helen Gahagan, representing the United Service Organization; Mr. Walter Wanger, President of the Academy of Motion Picture Arts & Sciences; Lt. Col. and Mrs. Chas. S. Stodter; Lt. Lewis Gough, U. S. N., and Mrs. Gough; Mr. Fred Jackman, President of the American Society of Cinematographers, and Mrs. Jackman; Dr. and Mrs. John G. Frayne; Mr. E. A. Williford; Mr. Arthur C. Downes; and Mr. George Friedl, Jr.

Brief addresses were made by Miss Gahagan, Messrs. Wanger and Jackman, Col. Stodter, and Lt. Gough.

On Thursday morning, at a meeting held at the General Service Studios, two additional parts of the symposium on the technic of motion picture production were presented. Part VII was devoted to "Cutting and Editing," by Frederick Richards of Warner Brothers and Fredrick Smith of M-G-M Studios, by arrangement with the Society of Motion Picture Film Editors. Mr. Carroll Dunning of the Dunning Process Co. presented the eighth part of the symposium, "Photographic Embellishment," including contributions from Farciot Edouart of Paramount, Fred Sersen of 20th Century-Fox Films, and John Fulton of Universal.

The Thursday evening session opened with the ninth part of the symposium, "Projection." This part was presented in two sections, one by George Urey of RCA Manufacturing Co., and the other by Herbert Starke of the RKO Service Corporation. Additional papers of the evening were devoted to various phases of sound recording and an interesting paper on the question of 16-mm emulsion position by Wm. H. Offenhauser, Jr., of Precision Film Laboratories.

On Friday mornng the session held at the Carthay Circle Theater opened with two papers by W. Jones and W. E. Garity, and E. H. Plumb, all of Walt Disney Productions, on "Theater Experiences with Fantasound" and "The Future of Fantasound." Additional papers dealt with the photographing of 16-mm Kodachrome short subjects for major studio release, by L. W. O'Connell of Warner Bros., and developments in time-saving process projection equipment, by R. W. Henderson of Paramount. The afternoon session was held at the Hotel, and included three papers on television technic and equipment by H. R. Lubcke of the Don Lee Broadcasting System, E. D. Cook of the General Electric Co., and G. L. Beers of the RCA Manufacturing Co.

The final session of the Convention, Friday evening, was devoted to papers on theater equipment, record reproduction systems, and a study of 16-mm projection flicker. These papers were presented by A. Goodman and E. Stanko, G. L. Beers and C. M. Sinnett, L. T. Sachtleben, and E. E. Masterson and E. W. Kellogg, all of RCA Manufacturing Co.

The Society wishes to acknowledge its gratitude to the large number of persons and companies who collaborated in providing the various facilities for the Convention. Acknowledgment is due also to Warner Brothers Hollywood Theater, Pantages' Hollywood Theater, Paramount Hollywood Theater, Grauman's Chinese and Egyptian Theaters, for the passes issued to Convention delegates during the dates of the Convention.

PROGRAM OF THE HOLLYWOOD CONVENTION*

MONDAY, MAY 4th

Noon: Hollywood-Roosevelt Hotel: Informal Get-Together Luncheon, Mr. Emery Huse, *presiding.*

Welcome by Mr. Cecil B. deMille, President of Cecil B. deMille Productions, Inc., Producing for Paramount Pictures, Inc., Hollywood, Calif.

Afternoon Session: Hollywood-Roosevelt Hotel: General Session; Herbert Griffin, *Chairman.*

Report of the Convention Vice-President, W. C. Kunzmann.

"Audio Visual Aids to Naval Training;" Wm. Exton, Jr., U. S. N. R., Bureau of Navigation, Navy Dept., Washington, D. C.

"The Motion Picture Camera in Army Air Forces;" Guy J. Newhard, U. S. Army Air Forces, Wright Field, Dayton, Ohio.

"Technical Progress in the Motion Picture Industry of the Soviet Union;" G. L. Irsky, Amtorg Trading Corp., New York, N. Y.

"The Application of Potentiometric Methods to Developer Analysis;" J. G. Stott, Eastman Kodak Co., New York, N. Y.

"Continuous Developer Replenishment and Chemical Control of Motion Picture Developing Solutions;" H. L. Baumbach, Paramount Pictures, Inc., Hollywood, Calif.

Evening Session: General Service Studios: Symposium on the Technic of Motion Picture Production; Emery Huse, *Chairman.*

The many technical processes through which a motion picture film passes from the time it leaves the manufacturer until it is shown in the theater were described, step by step, in a series of coördinated papers by authors especially qualified in each field. (The symposium covered the Monday evening, Tuesday afternoon, Thursday afternoon, and Thursday evening sessions.)

I. "Cinematography, 1942, Black and White;" John W. Boyle, Universal Pictures, Inc.; D. B. Clark, Twentieth Century-Fox Film Corp., Hollywood, Calif.; John Arnold, Metro-Goldwyn-Mayer Pictures, Culver City, Calif.

"Technicolor;" Winton Hoch, Technicolor Motion Picture Corp., Hollywood, Calif.

II. "Illumination;" R. G. Linderman, Mole-Richardson Co., Hollywood, Calif.; C. W. Handley, National Carbon Co., Hollywood, Calif.; Alston Rodgers, General Electric Co., Hollywood, Calif.; John W. Boyle, Universal Pictures, Inc., Hollywood, Calif.; and others.

III. "Laboratory Practices;" J. R. Wilkinson, Paramount Pictures, Inc., Hollywood, Calif.

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* As actually followed at the sessions.

TUESDAY, MAY 5th

Morning: Visit to Warner Bros. Laboratories, Burbank, Calif.; Fred Gage, *Superintendent.*

Afternoon Session: General Service Studios: Symposium on the Technic of Motion Picture Production; John G. Frayne, *Chairman.*

IV. "Production Sound;" H. G. Tasker, Paramount Pictures, Inc., Hollywood, Calif.

V. "Scoring and Prescoring;" Bernard Brown, Universal Pictures, Inc., Hollywood, Calif.

VI. "Re-Recording;" L. T. Goldsmith, Warner Bros. Pictures, Inc., Burbank, Calif.

"Motion Pictures: Technology in Art;" L. S. Becker, Warner Bros. Pictures Inc., Burbank, Calif.

Evening Session: Metro-Goldwyn-Mayer Studios; Sound Session; Arthur C. Downes, *Chairman.*

"An Analysis of the Complete Sound-Recording System Now Used by M-G-M Studios;" J. K. Hilliard, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

"Loop Synchronization;" Theodore Hoffman, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

WEDNESDAY, MAY 6th

Morning Session: Hollywood-Roosevelt Hotel: General Session; Edward M. Honan, *Chairman.*

"The Development of the Sound-Film, 1927–42;" J. E. Abbott, Museum of Modern Art Film Library, New York, N. Y.

Report of the Historical Committee; J. E. Abbott, *Chairman.*

"Concerning Photography as an Art in America;" L. E. Varden, Agfa Ansco, Binghamton, N. Y.

Report of the Theater Engineering Committee; Alfred N. Goldsmith, *Chairman.*

"Production of Industrial Motion Pictures;" Lloyd Thompson, The Calvin Company, Kansas City, Mo.

"Light-Scattering by Graininess of Photographic Emulsions;" Alexander Goetz and F. W. Brown, California Institute of Technology, Pasadena, Calif.

Afternoon: Paramount Studios: Demonstration of Equipment and Facilities of Television Productions, Inc., E. C. Buddy and K. Landsberg.

Evening Hollywood-Roosevelt Hotel: Fifty-First Semi-Annual Banquet and Dance. Dancing and entertainment.

THURSDAY, MAY 7th

Open Morning

Afternoon Session: General Service Studios: Symposium on the Technic of Motion Picture Production; Hollis Moyse, *Chairman.*

"A Proposed Standard for Determining the Effective Speed of Photographic Objectives;" E. W. Silvertooth, Paramount Pictures, Inc., Hollywood, Calif.

VII. "Cutting and Editing;" Frederick Richards, Warner Bros. Pictures, Inc., Burbank, Calif.; Fredrick Smith, Metro-Goldwyn-Mayer Studios, Culver City, Calif., by arrangement with the Society of Motion Picture Film Editors.

VIII. "Photographic Embellishment;" C. Dunning, Dunning Process Co., Hollywood, Calif.; Farciot Edouart, Paramount Pictures, Inc., Hollywood, Calif.; Fred Sersen, 20th Century-Fox Films, Hollywood, Calif.; John Fulton, Universal Pictures, Inc., Hollywood, Calif.

Evening Session: Hollywood-Roosevelt Hotel: Symposium on the Technic of Motion Picture Production; Loren L. Ryder, *Chairman.*

IX. "Projection;" George Urey, RCA Manufacturing Co., Inc., Hollywood, Calif., and Herbert Starke, RKO Service Corp., Hollywood, Calif.

Sound Session.

"Coördination of Facilities in the Sound Plant;" L. L. Ryder, Paramount Pictures, Inc., Hollywood, Calif.

"Motor Drive Systems for Motion Picture Production;" A. L. Holcomb, Elec. Research Prod. Div., Western Electric Co., Hollywood, Calif.

"A Program-Operated Level-Governing Amplifier;" W. L. Black and N. C. Norman, Bell Telephone Laboratories, New York, N. Y.

"Some Further Notes on the Question of 16-Mm Emulsion Position;" Wm. H. Offenhauser, Jr., Precision Film Laboratories, Inc., New York, N. Y.

"Recent Developments in Sound Control for the Theater and Opera;" H. Burris-Meyer, Stevens Institute of Technology, Hoboken, N. J.

FRIDAY, MAY 8th

Morning Session: Carthay Circle Theater: General Session; Charles W. Handley, *Chairman.*

"Theater Experiences with Fantasound;" W. Jones, RCA Mfg. Co., Inc., Hollywood, Calif., and W. E. Garity, Walt Disney Productions, Hollywood, Calif.

"The Future of Fantasound;" E. H. Plumb, Walt Disney Productions, Hollywood, Calif.

"Elimination of Relative Spectral Energy Distortion in Electronic Compressors;" B. F. Miller, Warner Bros., Burbank, Calif.

"The Photographing of 16-Mm Kodachrome Short Subjects for Major Studio Release;" L. W. O'Connell, Warner Bros. First National Studios, Burbank, Calif.

"The Practical Aspect of Edge-Numbering 16-Mm Film;" H. A. Witt, Wilding Picture Productions, Inc., Chicago, Ill.

"Developments in Time-Saving Process Projection Equipment;" R. W. Henderson, Paramount Pictures, Inc., Hollywood, Calif.

Afternoon Session: Hollywood-Roosevelt Hotel: General Session; W. W. Lindsay, Jr., *Chairman.*

"The Engineering Aspects of Portable Television Pick-Ups;" H. R. Lubcke, Don Lee Broadcasting System, Hollywood, Calif.

"The General Electric Television Projector;" E. D. Cook, General Electric Company, Schenectady, N. Y.

"The Focusing View-Finder Problem in Television Cameras;" G. L. Beers, RCA Manufacturing Co., Inc., Camden, N. J.

"Procedural and Dimensional Practices for Production of 16-Mm Motion Pictures for Television Projection;" R. Blackinton Fuller and L. S. Rhodes, Marsh Cinesound, Inc., New York, N. Y.

"The Defense Program of the Motion Picture Theater;" Henry Anderson, Paramount Pictures, Inc., New York, N. Y.

Evening Session: Hollywood-Roosevelt Hotel: Sound Session; Barton Kreuzer, *Chairman.*

"RCA Audio Chanalyst—A New Instrument for the Theater Sound Engineer;" A. Goodman and E. Stanko, RCA Manufacturing Co., Inc., Camden, N. J.

"Some Recent Develòpments in Record Reproducing Systems;" G. L. Beers and C. M. Sinnett, RCA Manufacturing Co., Inc., Camden, N. J.

"A One-Ray System for Designing Spherical Condensers;" L. T. Sachtleben, RCA Manufacturing Co., Inc., Indianapolis, Ind.

"Frequency Modulation Distortion in Loudspeakers;" G. L. Beers and H. Belar, RCA Manufacturing Co., Inc., Camden, N. J.

"A Study of Flicker in 16-Mm Picture Projection;" E. E. Masterson and E. W. Kellogg, RCA Mfg. Co., Inc., Indianapolis, Ind.

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION

At a meeting held at the Hotel Pennsylvania, New York, N. Y., on May 21st, a paper on the subject of "Wartime Conservation in Theater Projection" was presented by the Theater Engineering Committee of the Society. The paper was based upon a set of ten points originally prepared and announced to the press by Mr. Richard Walsh of the IATSE and MPMO. The present paper was an elaboration of the ten points with specific instructions to projectionists on how to achieve the conservation so vitally necessary at the present time.

The paper on conservation was followed by a presentation by Mr. Henry Anderson of Paramount Pictures, Inc., on the subject of "The Defense Program of the Motion Picture Theater."

The meeting was very well attended, and included quite a number of projectionists from the various theater circuits. A lively discussion followed the presentations.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, the following applicants for membership were admitted into the Society in the Associate grade:

BOYLE, C. A.
1511 Jackson Ave.,
Chicago, Ill.

COSTELLO, J. V.
c/o National Carbon Co., Inc.,
1810 Clark Bldg.,
Pittsburgh, Pa.

DEPEW, C. E.
Windsor,
New York

DEWHIRST, T. P.
138 Fernwood Terrace,
Stewart Manor, L. I., N. Y.

DU PATY, FRANK
The Explorers Club,
10 W. 72nd St.,
New York, N. Y.

KONTOS, CONSTANTINE J.
7952 S. Vernon Ave.,
Chicago, Ill.

LOOMIS, H. ARTHUR
43 So. Washington St.,
Rochester, N. Y.

LURCOTT, E. G.
c/o RCA Mfg. Co., Inc.,
501 N. LaSalle St.,
Indianapolis, Ind.

MESEROW, F. P.
3149 Lyndale Ave.,
Chicago, Ill.

RIABOV, A. P.
c/o Amtorg Trading Corp.,
210 Madison Ave.,
New York, N. Y.

VOLPE, FRANK
4942 Wrightwood Ave.,
Chicago, Ill.

YOUNG, R. A.
Box 1123,
Homestead, Fla.

In addition, the following applicants have been admitted to the Active grade:

BADGELY, G. J.
Galesville,
Md.

CHRISTIE, JOHN
Eastman Kodak Company,
333 State St.,
Rochester, N. Y.

HUNGERFORD, O. W.
Marsh Cinesound, Inc.,
17 West 60th St.,
New York, N. Y.

KEARNEY, R. E.
Motion Picture Section,
The Engineer Board,
Ft. Belvoir, Va.

RUMMEL, E. T.
The Hertner Electric Co.,
12690 Elmwood Ave.,
Cleveland, Ohio

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

AUTHOR AND CLASSIFIED
INDEXES

VOLUME XXXVIII
JANUARY–JUNE, 1942

AUTHOR INDEX, VOLUME XXXVIII

JANUARY TO JUNE, 1942

Author		*Issue*	*Page*
ABBOTT, J. E.	The Development of the Sound-Film	June	541
ALBERSHEIM, W. J. (and BROWN, L. F.)	Stabilized Feedback Light-Valve	Mar.	240
ANDERSON, H.	The Defense Program of the Motion Picture Theater	June	526
BELL, W. L. (and SCOVILLE, R. R.)	Design and Use of Noise-Reduction Bias Systems	Feb.	125
BOECKING, E. (and DAVEE, L. W.)	Recent Developments in Projection Mechanism Design	Mar.	262
BROWN, L. F. (and ALBERSHEIM, W. J.)	Stabilized Feedback Light-Valve	Mar.	240
CHAMBERS, I. M. (and DAILY, C. R.)	Production and Release Applications of Fine-Grain Films for Variable-Density Sound-Recording	Jan.	45
CRABTREE, J. I. (and MUEHLER, L. E., and RUSSELL, H. D.)	New Stop Bath and Fixing Bath Formulas and Methods for Their Revival	Apr.	353
DAILY, C. R. (and CHAMBERS, I. M.)	Production and Release Applications of Fine-Grain Films for Variable-Density Sound-Recording	Jan.	45
DAVEE, L. W. (and BOECKING, E.)	Recent Developments in Projection Mechanism Design	Mar.	262
DIMMICK, G. L.	A New Dichroic Reflector and Its Application to Photocell Monitoring Systems	Jan.	36
DYER, J. N. (and GOLDMARK, P. C., and HOLLYWOOD, J. M., and E. R. PIORE)	Color Television	Apr.	311
EICH, F. L. (and WILKINSON, J. R.)	Laboratory Modification and Procedure in Connection with Fine-Grain Release Printing	Jan.	56
EVANS, R. M. (and HANSON, W. T., JR., and GLASOE, P. K.)	Iodide Analysis in an MQ Developer	Feb.	180
	Synthetic Aged Developers by Analysis	Feb.	188
EXTON, WM. JR.	The Navy's Use of Motion Picture Films for Training Purposes	June	501

Author		*Issue*	*Page*
FRAYNE, J. G. (and HERRNFELD, F. P.)	A Frequency-Modulated Control-Track for Movietone Prints	Feb.	111
GLASOE, P. K. (and EVANS, R. M., and HANSON, W. T., JR.)	Iodide Analysis in an MQ Developer	Feb.	180
	Synthetic Aged Developers by Analysis	Feb.	183
GOLDMARK, P. C. (and DYER, J. N., and HOLLYWOOD, J. M., and PIORE, E. R.)	Color Television	Apr.	311
GOLDSMITH, ALFRED N.	The IR System: An Optical Method for Increasing Depth of Field	Jan.	3
GRIFFITH, R.	Adventures of a Film Library	Mar.	284
HANSON, W. T., JR. (and EVANS, R. M., and GLASOE, P. K.)	Iodide Analysis in an MQ Developer	Feb.	180
	Synthetic Aged Developers by Analysis	Feb.	188
HERRNFELD, F. P. (and FRAYNE, J. G.)	A Frequency-Modulated Control-Track for Movietone Prints	Feb.	111
HOLLYWOOD, J. M. (and DYER, J. N., and GOLDMARK, P. C., and PIORE, E. R.)	Color Television	Apr.	311
HOTINE, W.	A Constant-Torque Friction Clutch for Film Take-Up	Mar.	256
IRSKY, G. L.	Technical Progress in the Motion Picture Industry of the Soviet Union	June	532
JONES, M. T. (and JOY, D. B., and LOZIER, W. W.)	New 13.6-Mm Carbons for Increased Screen Light	Mar.	229
JOY, D. B. (and LOZIER, W. W., and NULL, M. R.)	The Color of Light on the Projection Screen	Mar.	219
JOY, D. B. (and JONES, M. T., and LOZIER, W. W.)	New 13.6-Mm Carbons for Increased Screen Light	Mar.	229
LEVINSON, N.	Sound in Motion Pictures	May	468
LOZIER, W. W. (and JOY, D. B., and NULL, M. R.)	The Color of Light on the Projection Screen	Mar.	219
LOZIER, W. W. (and JONES, M. T., and JOY, D. B.)	New 13.6-Mm Carbons for Increased Screen Light	Mar.	229
MACPHERSON, H. G.	The Consumption of the Positive Arc Carbon	Mar.	235

MOGENSEN, A. H.	Work Simplification—Essential to Defense	Mar.	295
MUEHLER, L. E. (and CRABTREE, J. I., and RUSSELL, H. D.)	New Stop Bath and Fixing Bath Formulas and Methods for Their Revival	Apr.	353
NEWHARD, G. J.	The Motion Picture Camera in the Army Air Forces	June	510
NULL, M. R. (and JOY, D. B., and LOZIER, W. W.)	The Color of Light on the Projection Screen	Mar.	219
PIORE, E. R. (and DYER, J. N., and GOLDMARK, P. C., and HOLLYWOOD, J. M.)	Color Television	Apr.	311
REICHES, S. L.	The Quarter-Wave Method of Speaker Testing	May	457
ROSENBERG, R.	An Analysis of the Application of Fluorescent Lamps to Motion Picture Photography	Feb.	173
RUSSELL, H. D. (and CRABTREE, J. I., and MUEHLER, L. E.)	New Stop Bath and Fixing Bath Formulas and Methods for Their Revival	Apr.	353
SCOVILLE, R. R. (and BELL, W. L.)	Design and Use of Noise-Reduction Bias Systems	Feb.	125
SHANER, V. C.	A Note on the Processing of Eastman 1302 Fine-Grain Release Positive in Hollywood	Jan.	66
SWEET, M. H.	A Precision Direct-Reading Densitometer	Feb.	148
THOMPSON, L.	Some Equipment Problems of the Direct 16-Mm Producer	Jan.	89
VARDEN, L. E.	Concerning Photography as an Art in America	June	549
WILKINSON, J. R. (and EICH, F. L.)	Laboratory Modification and Procedure in Connection with Fine-Grain Release Printing	Jan.	56

CLASSIFIED INDEX, VOLUME XXXVIII

JANUARY TO JUNE, 1942

Apparatus

A Constant-Torque Friction Clutch for Film Take-Up, W. Hotine, No. 3 (March), p. 256.

Recent Developments in Projection Mechanism Design, E. Boecking and L. W. Davee, No. 3 (March), p. 262.

Applications of Motion Pictures

Work Simplification—Essential to Defense, A. H. Mogensen, No. 3 (March), p. 295.

The Navy's Use of Motion Picture Films for Training Purposes, Wm. Exton, Jr., No. 6 (June), p. 501.

The Motion Picture Camera in the Army Air Forces, Guy G. Newhard, No. 6 (June), p. 510.

The Defense Program of the Motion Picture Theater, Henry Anderson, No. 6 (June), p. 526.

Technical Progress in the Motion Picture Industry of the Soviet Union, G. L. Irsky, No. 6 (June), p. 532.

Arcs

The Color of Light on the Projection Screen, M. R. Null, W. W. Lozier and D. B. Joy, No. 3 (March), p. 219.

New 13.6-Mm Carbons for Increased Screen Light, M. T. Jones, W. W. Lozier and D. B. Joy, No. 3 (March), p. 229.

The Consumption of the Positive Arc Carbon, H. G. MacPherson, No. 3 (March), p. 235.

Army, U. S.

The Motion Picture Camera in the Army Air Forces, Guy J. Newhard, No. 6 (June), p. 510.

Committee Reports

Theater Engineering, No. 1 (Jan.), p. 74; No. 6 (June), p. 515.

Standards, No. 1 (Jan.), p. 87; No. 5 (May), p. 403.

Studio Lighting, No. 3 (March), p. 281.

Historical, No. 6 (June), p. 546.

Committees of the Society

No. 4 (April), p. 377.

Conservation

Wartime Conservation in Theater Projection—A Contribution by the Projection Practice Sub-Committee of the Theater Engineering Committee, No. 6 (June), p. 515.

Constitution and By-Laws of the Society
No. 4 (April), p. 382.

Control-Track
A Frequency-Modulated Control-Track for Movietone Prints, J. G. Frayne and F. P. Herrnfeld, No. 2 (Feb.), p. 111.
A Precision Direct-Reading Densitometer, M. H. Sweet, No. 2 (Feb.), p. 148.

Depth of Field
The IR System: An Optical Method for Increasing Depth of Field, Alfred N. Goldsmith, No. 1 (Jan.), p. 3.

Development, Photographic
Iodide Analysis in an MQ Developer, R. M. Evans, W. T. Hanson, Jr., and P. K. Glasoe, No. 2 (Feb.), p. 180.
Synthetic Aged Developers by Analysis, R. M. Evans, W. T. Hanson, Jr., and P. K. Glasoe, No. 2 (Feb.), p. 188.

Dichroism
A New Dichroic Reflector and Its Application to Photocell Monitoring Systems, G. L. Dimmick, No. 1 (Jan.), p. 36.

Film, Photographic Characteristics
A Note on the Processing of Eastman 1302 Fine-Grain Release Positive in Hollywood, V. C. Shaner, No. 1 (Jan.), p. 66.

Fine-Grain Film
Laboratory Modification and Procedure in Connection with Fine-Grain Release Printing, J. R. Wilkinson and F. L. Eich, No. 1 (Jan.), p. 56.
A Note on the Processing of Eastman 1302 Fine-Grain Release Positive in Hollywood, V. C. Shaner, No. 1 (Jan.), p. 66.

Fixing Motion Picture Film
New Stop Bath and Fixing Bath Formulas and Methods for Their Revival, J. I. Crabtree, L. E. Muehler, and H. D. Russell, No. 4 (April), p. 353.

Fluorescent Lamps
An Analysis of the Application of Fluorescent Lamps to Motion Picture Photography, R. Rosenberg, No. 2 (Feb.), p. 173.

General
Adventures of a Film Library, R. Griffith, No. 3 (March), p. 284.
Work Simplification—Essential to Defense, A. H. Morgensen, No. 3 (March), p. 295.
Sound in Motion Pictures, N. Levinson, No. 5 (May), p. 468.

Historical
Work Simplification—Essential to Defense, A. H. Morgensen, No. 3 (March), p. 295.
Sound in Motion Pictures, N. Levinson, No. 5 (May), p. 468.
Technical Progress in the Motion Picture Industry of the Soviet Union, G. L. Irsky, No. 6 (June), p. 532.

The Development of the Sound-Film, J. E. Abbott, No. 6 (June), p. 541.
Edwin S. Porter, No. 6 (June), p. 549.
Concerning Photography as an Art in America, L. E. Varden, No. 6 (June), p. 549.

Illumination
An Analysis of the Application of Fluorescent Lamps to Motion Picture Photography, R. Rosenberg, No. 2 (Feb.), p. 173.
The Color of Light on the Projection Screen, M. R. Null, W. W. Lozier, and D. B. Joy, No. 3 (March), p. 219.
New 13.6-Mm Carbons for Increased Screen Light, M. T. Jones, W. W. Lozier, and D. B. Joy, No. 3 (March), p. 229.
The Consumption of the Positive Arc Carbon, H. G. MacPherson, No. 3 (March), p. 235.
Report of the Studio Lighting Committee, No. 3 (March), p. 281.

Index
Author, January–June, 1942, No. 6 (June), p. 570.
Classified, January–June, 1942, No. 6 (June), p. 573.

Increased Range System
The IR System: An Optical Method for Increasing Depth of Field, Alfred N. Goldsmith, No. 1 (Jan.), p. 3.

Industrial Films
Some Equipment Problems of the Direct 16-Mm Producer, L. Thompson, No. 1 (Jan.), p. 89.

Instruments
A Precision Direct-Reading Densitometer, M. H. Sweet, No. 2 (Feb.), p. 148.

Laboratory Practices
Laboratory Modification and Procedure in Connection with Fine-Grain Release Printing, J. R. Wilkinson and F. L. Eich, No. 1 (Jan.), p. 56.

Libraries
Adventures of a Film Library. R. Griffith, No. 3 (March), p. 284.

Light-Valves
Stabilized Feedback Light-Valve, W. J. Albersheim and L. F. Brown, No. 3 (March), p. 240.

Lighting, Studio
The IR System: An Optical Method for Increasing Depth of Field, Alfred N. Goldsmith, No. 1 (Jan.), p. 3.

Loud Speakers
The Quarter-Wave Method of Speaker Testing, S. L. Reiches, No. 5 (May), p. 457

Mechanisms
A Constant-Torque Friction Clutch for Film Take-Up, W. Hotine, No. 3 (March), p. 256.

Recent Developments in Projection Mechanism Design, E Boecking and L. W. Davee, No. 3 (March), p. 262.

Navy, U. S.

The Navy's Use of Motion Picture Films for Training Purposes, Wm. Exton, Jr., No. 6 (June), p. 501.

Noise Reduction

Design and Use of Noise-Reduction Bias Systems, R. R. Scoville and W. L. Bell, No. 2 (Feb.), p. 125.

Non-Theatrical

Some Equipment Problems of the Direct 16-Mm Producer, L. Thompson, No. 1 (Jan.), p. 89

Officers and Governors of the Society

On the reverse of the Contents Page of each issue.
Photographs, No. 3 (April), p. 374.

Optics

The IR System: An Optical Method for Increasing Depth of Field, Alfred N. Goldsmith, No. 1 (Jan.), p. 3.

A New Dichroic Reflector and Its Application to Photocell Monitoring Systems, G. L. Dimmick, No. 1 (Jan.), p. 36.

Photoelectric Cells

A New Dichroic Reflector and Its Application to Photocell Monitoring Systems, G. L. Dimmick, No. 1 (Jan.), p. 36.

Processing

A Note on the Processing of Eastman 1302 Fine-Grain Release Positive in Hollywood, V. C. Shaner, No. 1 (Jan.), p. 66.

Iodide Analysis in an MQ Developer, R. M. Evans, W. T. Hanson, Jr., and P. K. Glasoe, No. 2 (Feb.), p. 180.

Synthetic Aged Developers by Analysis, R. M. Evans, W. T. Hanson, Jr., and P. K. Glasoe, No. 2 (Feb.), p. 188.

New Stop Bath and Fixing Bath Formulas and Methods for Their Revival, J. I. Crabtree, L. E. Muehler, and H. D. Russell, No. 3 (April), p. 353.

Projection Practice

Report of the Theater Engineering Committee, No. 1 (Jan.), p. 74.

Wartime Conservation in Theater Projection—A Contribution by the Projection Practice Sub-Committee of the Theater Engineering Committee, No. 6 (June), p. 515.

Projectors

A Constant-Torque Friction Clutch for Film Take-Up, W. Hotine, No. 3 (March), p. 256.

Recent Developments in Projection Mechanism Design, E. Boecking and L. W. Davee, No. 3 (March), p. 262.

Release Printing

Production and Release Applications of Fine-Grain Films for Variable-Density Sound-Recording, C. R. Daily and I. M. Chambers, No 1 (Jan.), p. 45.

Laboratory Modification and Procedure in Connection with Fine-Grain Release Printing, J. R. Wilkinson and F. L. Eich, No. 1 (Jan.), p. 56.
A Note on the Processing of Eastman 1302 Fine-Grain Release Positive in Hollywood, V. C. Shaner, No. 1 (Jan.), p. 66.
A Frequency-Modulated Control-Track for Movietone Prints, J. G. Frayne and F. P. Herrnfeld, No. 2 (Feb.), p. 111.

Screen Brightness
Report of the Theater Engineering Committee, No. 1 (Jan.), p. 74.
The Color of Light on the Projection Screen, M. R. Null, W. W. Lozier, and D. B. Joy, No. 3 (March), p. 219.
New 13.6-Mm Carbons for Increased Screen Light, M. T. Jones, W. W. Lozier, and D. B. Joy, No. 3 (March), p. 229.

Sixteen Millimeter
Some Equipment Problems of the Direct 16-Mm Producer, L. Thompson, No. 1 (Jan.), p. 89.

Sound Recording
A New Dichroic Reflector and Its Application to Photocell Monitoring Systems, G. L. Dimmick, No. 1 (Jan.), p. 36.
Laboratory Modification and Procedure in Connection with Fine-Grain Release Printing, J. R. Wilkinson and F. L. Eich, No. 1 (Jan.), p. 56.
A Frequency-Modulated Control-Track for Movietone Prints, J. G. Frayne and F. P. Herrnfeld, No. 2 (Feb.), p. 111.
Design and Use of Noise-Reduction Bias Systems, R. R. Scoville and W. L. Bell, No. 2 (Feb.), p. 125.
Stabilized Feedback Light-Valve, W. J. Albersheim and L. F. Brown, No. 3 (March), p. 240.

Sound Reproduction
The Quarter-Wave Method of Speaker Testing, S. L. Reiches, No. 5 (May), p. 457.

Standards
Report of the Standards Committee, No. 1 (Jan.), p. 87.
Recommended Practices of the Society of Motion Picture Engineers, No. 5 (May), p. 403.

Studio Equipment
The IR System: An Optical Method for Increasing Depth of Field, Alfred N. Goldsmith, No. 1 (Jan.), p. 3.

Studio Lighting
Report of the Studio Lighting Committee, No. 3 (March), p. 281.

Television
Color Television, P. C. Goldmark, J. N. Dyer, E. R. Piore, and J. M. Hollywood, No. 4 (April), p. 311.

Theater Design
Report of the Theater Engineering Committee, No. 1 (Jan.), p. 74.

Theater Engineering
Report of the Theater Engineering Committee, No. 1 (Jan.), p. 74.

BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

Prior to January, 1930, the *Transactions* of the Society were published quarterly. A limited number of these *Transactions* are still available and will be sold at the prices listed below. Those who wish to avail themselves of the opportunity of acquiring these back numbers should do so quickly, as the supply will soon be exhausted, especially of the earlier numbers. It will be impossible to secure them later on as they will not be reprinted.

	No.	Price
1924	19	$1.25
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	27	1.25
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1928	33	$2.50
	34	2.50
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Beginning with the January, 1930, issue, the JOURNAL of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers of all issues are available at the price of $1.00 each, a complete yearly issue totalling $12.00. Single copies of the current issue may be obtained for $1.00 each. Orders for back numbers of *Transactions* and JOURNALS should be placed through the General Office of the Society and should be accompanied by check or money-order.

SOCIETY SUPPLIES

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

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

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

Motion Picture Standards.—Reprints of the *American Standards and Recommended Practices* as published in the March, 1941, issue of the JOURNAL; 50 cents each.

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

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

Test-Films.—See advertisement in this issue of the JOURNAL.

S. M. P. E. TEST-FILMS

These films have been prepared under the supervision of the Projection Practice Committee of the Society of Motion Picture Engineers, and are designed to be used in theaters, review rooms, exchanges, laboratories, factories, and the like for testing the performance of projectors.

Only complete reels, as described below, are available (no short sections or single frequencies). The prices given include shipping charges to all points within the United States; shipping charges to other countries are additional.

35-Mm. Visual Film

Approximately 500 feet long, consisting of special targets with the aid of which travel-ghost, marginal and radial lens aberrations, definition, picture jump, and film weave may be detected and corrected.

Price $37.50 each.

16-Mm. Sound-Film

Approximately 400 feet long, consisting of recordings of several speaking voices, piano, and orchestra; buzz-track; fixed frequencies for focusing sound optical system; fixed frequencies at constant level, for determining reproducer characteristics, frequency range, flutter, sound-track adjustment, 60- or 96-cycle modulation, etc.

The recorded frequency range of the voice and music extends to 6000 cps.; the constant-amplitude frequencies are in 11 steps from 50 cps. to 6000 cps.

Price $25.00 each.

16-Mm. Visual Film

An optical reduction of the 35-mm. visual test-film, identical as to contents and approximately 225 feet long.

Price $25.00 each.

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

Society of Motion Picture Engineers

HOTEL PENNSYLVANIA
NEW YORK, N. Y.

APPLICATION FOR MEMBERSHIP

APPLICANT'S RECORD

Name.....Age.....

Mailing Address.....

Present Occupation.....

Employer.....

A complete account of the applicant's qualifications and accomplishments is required before an application may be submitted to the Board of Governors. The applicant should describe any inventions and improvements he has made in the art, as these are considered of more importance than a mere record of experience or the names of positions the applicant has filled.

Education.....

.....

Record of Accomplishments.....

.....

Motion Picture Experience.....

.....

Grade Applied For.....
(Active, Associate, or Student)

REFERENCES

1. ..... 3. .....
....
2. ..... 4. .....
....

The undersigned certifies that the above statements are correct, and agrees, if elected to membership, that he will be governed by the Society's Constitution and By-Laws so long as his connection with the Society continues.

Date.....19... *Signed*.....

(*Use a separate sheet of paper for complete record of accomplishments*)