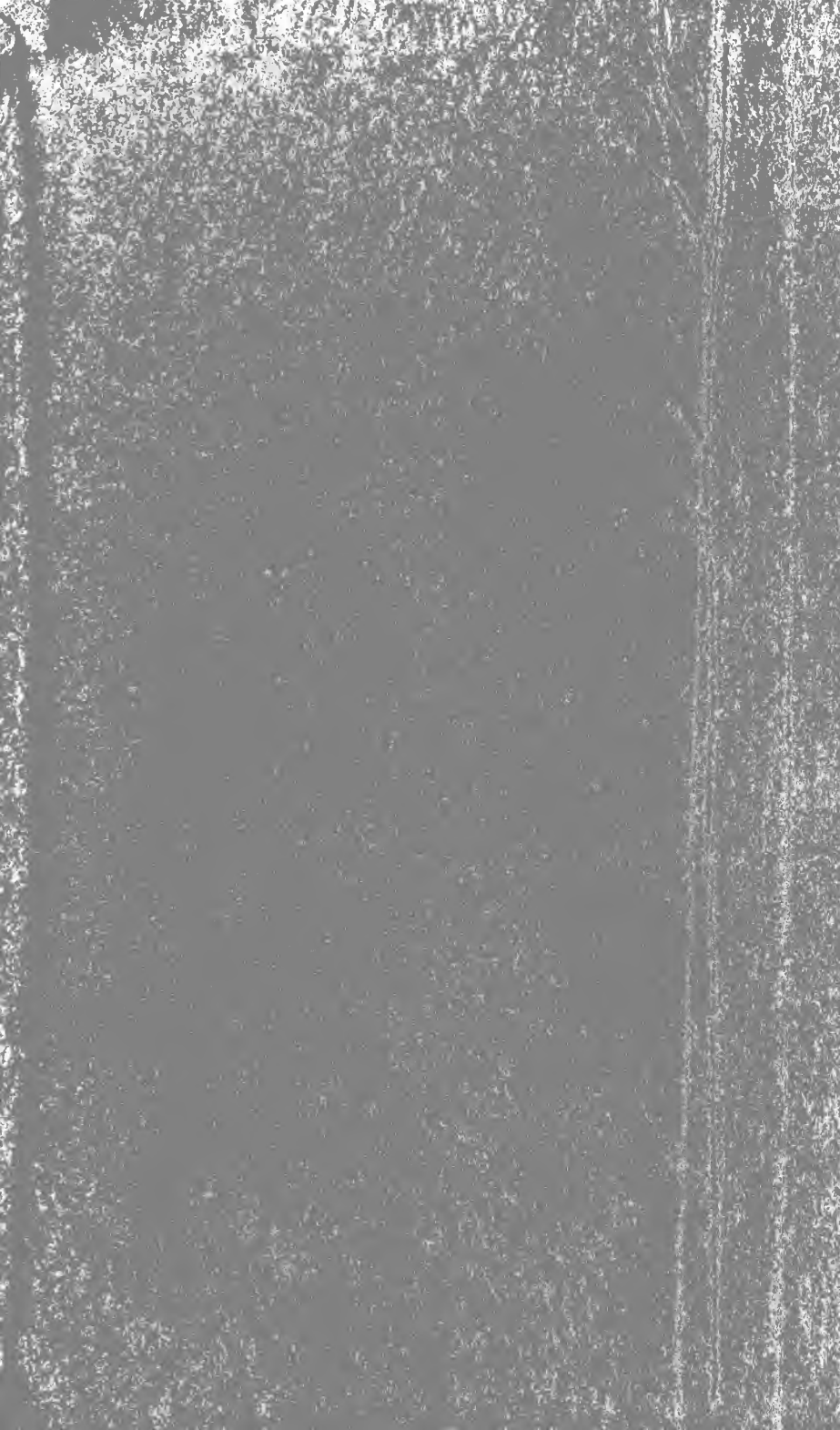


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JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

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MOTION PICTURE STANDARDS IN WARTIME*

DONALD E. HYNDMAN**

An American bomber is zooming its way to enemy territory on an important mission of destruction. It reaches the outskirts of its destination, loses altitude, the bomb-bay doors are opened. The bombardier sights his target, the bombs are released. The photographer aims his motion picture camera as the bombs fall and presses the release lever—it starts—groans and stops—dead. The bomber returns to base with no photographic record to show whether a “hit” or a “miss” was made. Why did the camera fail? Was the diameter of the sprockets too great or too small? Was the film perforated under- or over-pitch for the sprockets? Was the film core binding on the spindle because it was too wide? Was the failure caused by non-interchangeability of parts and materials?

Of course, such an incident did not occur because standards were employed in manufacturing the camera, accessories, and film. Standards avoid such dangers. Standards provide interchangeability, simplification of groups of articles, economies in manufacture, agreement between purchaser and purveyor on specifications, and avoid entanglements and misunderstandings.

To avoid misconception and to acquaint the uninitiated, it seems best that definitions of the terms and concise descriptions of the methods employed in standardization procedure be given as an introduction to Motion Picture Standards. The following definition of an SMPE Recommended Practice has been approved by the Board of Governors and the Standards Committee of the Society of Motion Picture Engineers. The following definition of an American Standard has been approved by the executive-secretary of the American Standards Association.

SMPE Recommended Practice.—An SMPE Recommended Practice is a description of a recommended process, method, construction, or device intended to accomplish a specific and desired aim. This issuance of such a Recommended

* Presented at the 1943 Spring Meeting at New York, N. Y.

** Engineering Vice-President of the Society.

Practice indicates that it is acceptable to the Standards Committee and to the Board of Governors of the Society of Motion Picture Engineers. Its publication by the SMPE constitutes a recommendation to interested parties that it be utilized as a habitual procedure, and that comments or criticisms concerning its effectiveness in practice are welcomed and will be considered.

American Standard.—American Standard is a form of approval given by the American Standards Association to specifications, safety codes, methods of test, definitions, abbreviations, and the like. Its adoption and publication by the authorization of the American Standards Association recommend to interested parties that it be accepted as a standard in industry, commerce, and elsewhere because it is believed to be technically, scientifically, and industrially effective and acceptable. An American Standard, having been approved according to a prescribed democratic procedure by a nationally recognized body of technical and scientific experts or specialists drawn from engineering organizations, industry, the government, consumers, and other legitimately interested groups, will normally receive full approval and acceptance in practice by a wide group of users.

Under the heading of Specifications would be included tables of dimensions with tolerances necessary to insure interchangeability in quantity production as well as requirements of a chemical, physical, or metallurgical nature necessary to insure a quality. Specifications, of course, may also include a definite and specific method of test.

The general standardization procedure is based upon the democratic method that a proposal, to become an SMPE Recommended Practice or American Standard, may be originated or proposed either singly or collectively by any interested person, group, commercial organization, or scientific, technical, or engineering society, *etc.*

A proposal when submitted to the SMPE is referred to the Standards Committee. This committee is composed of authoritative engineers and technicians of the motion picture industry, representing producers, distributors, exhibitors, and manufacturers of all types of equipment utilized in the industry. The Committee follows a very specific procedure prescribed by the Administrative Practices of the Society. The Committee carefully studies the proposal, prepares the necessary forms, and requests written comment from interested parties before deciding whether the proposal should be classified for consideration as an SMPE Recommended Practice or for submission to the American Standards Association recommending its consideration for an American Standard.

Following approval of the proposal by the Standards Committee, it is submitted to the Board of Governors and, if approved, is published in the JOURNAL with an announcement of its validation as an SMPE Recommended Practice.

It is unlikely, however, that a proposal would not first become an

SMPE Recommended Practice before being considered for or becoming an American Standard because as an SMPE Recommended Practice it constitutes a recommendation to interested parties that it be utilized as a habitual procedure and that comments or criticisms concerning its effectiveness in practice are welcome and will be considered. This procedure gives all interested parties ample time to try thoroughly the recommendation before it is advanced to the higher status of a standard.

When a proposal, whether it be merely a new project or an SMPE Recommended Practice, is submitted to the ASA for consideration as an American Standard, it is referred to the Sectional Committee on Motion Pictures, Z-22. This Sectional Committee, composed of representative technical and engineering authorities from the motion picture industry, representing producers, distributors, exhibitors, and manufacturers of all types of motion picture equipment, carefully studies the proposal, arranges the form, and requests comments from all interested parties. If the project is approved, the Sectional Committee forwards its recommendation to the parent body, the American Standards Association. The ASA now studies the recommendation of the Sectional Committee and, if approved, an American Standard is issued with announcement of validation by the "supreme court" of American standardization.

Obviously many important details are left out of this description of the standardization procedure, but space permits mention of only the important features of the process. An important point is that there are no SMPE Standards. Only SMPE *Recommended Practices* exist; and only the ASA has the right to validate *American Standards*. There have been no American Recommended Practices since February, 1943.

Few persons realize the value of standardization procedures. They may do so subconsciously in their daily lives and tasks but they do not realize that the food they eat, the clothes they wear, the cosmetics, detergents, and the luxuries they buy, as well as the tools necessary to process and fabricate practically all the materials and products, are the results of the work of technicians and engineers who have spent many days, weeks, and months on the problems of standardizing both the articles manufactured and the processes of manufacturing them so as to assure consistent-quality mass-production of the things that contribute to better living. Standardization speeds up production, refines individual and collective quality control,

maintains a consistent level and dispersion of quality and quantity, provides means for rapid inspection and sampling, produces normal distribution of quality and quantity, and brings to the consumer a uniform product. In addition, it promotes interchangeability of specific products serving the same purpose, allowing the consumer to choose products on the basis of quality, service, and utility. It thus constitutes an economic saving and a major convenience to producer and consumer alike.

In current circumstances we apply peacetime knowledge to wartime practice; and when this war is over, both peacetime and wartime knowledge will be applied to postwar practice. The last war necessitated standardization to increase production, to husband the use of scarce materials, to create new uses for available substitutes, and to develop new materials and new processes. These developments did much to provide better living conditions and to bring greater happiness to the people of the world in the quarter-century prior to the starting of this war. Unfortunately, alien and destructive forces partly annulled these gains. In the developments following the present world conflict probably even greater improvements will take place because the speed of production and efficiency of destruction in this war has proceeded at a much greater rate, demanding more materials and more accurate machinery of war. This demand has forced a rapid development of new materials as substitutes for scarce materials. Sometimes the substitutes prove better in many ways than the original material. The same will be true in the "postwar" period.

Since Pearl Harbor, "War Model Standards" have been evolved and put into commercial practice in many fields of endeavor. This has been rapidly accomplished through the coöperation of industry, government agencies, such as the War Production Board, Office of Price Administration, *etc.*, the technical and engineering societies, and the American Standards Association. This coöperation has resulted in radical reductions in the thousands of items produced in some fields. It has also, in many instances, brought about simplification of models, utilization of substitute materials, and increased production of fewer items. The effort has netted great savings of scarce materials for more important purposes, and has efficiently conserved both essential and non-vital goods.

In the electrical field, from approximately several hundred types of electronic tubes, capacitors, volume controls, power transformers, chokes, transformers, *etc.*, the new "War Model Standards" have

reduced the number of types to approximately one to twenty-five, depending upon how readily interchangeability can be effected. The performance and design standards provide for using a minimum of strategic materials, but being satisfactory from an electrical and service life standpoint to avoid, if possible, replacing replacement parts. New specifications for insulators and insulating pieces cover performance characteristics, preferred shapes, and interchangeability for various types of ceramic materials to assure the availability of needed parts. Such standards are of vital interest to the motion picture industry as they apply to electrical equipment, sound recording and reproducing equipment, sound projectors, power supplies for studio lighting and theaters, general wiring, *etc.*

Many substitutes for strategic materials have been evolved. In many types of electrical wiring installations copper wire is covered with synthetic plastic material which serves as insulation in place of rubber. A mixture of plastic and cotton cord provides material to fabricate liquid-carrying hose in place of the rubber and cord hose formerly used. A number of motion picture laboratories are using synthetic plastic tubing to replace flexible rubber hose or hard-rubber pipe for carrying photographic solutions to and from continuous developing machines. This plastic tubing can be obtained in a wide variety of wall thicknesses and diameters, and it can not only be bent at any angle, avoiding the use of elbows, but can also be threaded for joints when desired, like all hard-rubber and metal pipe. Plastic sheets, tubes, and rods are now finding utility where before it was believed only stainless steel or rubber could be safely used.

Such developments are the results of standardization in wartime. It must always be the object to effect interchangeability of parts and materials, to utilize substitutes for strategic materials whenever possible, to minimize the number of items of any one type, to specify preferred shapes, to maintain performance and life characteristics comparable to or better than those of the original items, and to minimize replacements.

There are fields waiting for further enrichment. Much can be done to standardize the equipment and procedures of motion picture production, distribution, and exhibition. Improvements can be made, with proper specification of new materials and processes, that will produce more goods at lower cost. For instance, there is evidence that continuous developing machines and printers can be sufficiently improved in design to increase the footage output per man-hour two to four-fold, and obtain a quality of product equivalent

to, or even better than, current products. Accessory equipment like manual and semi-automatic rewinds, hand and machine splicing equipment, cutting and editing equipment, requires more efficient design. A study of the tooth shapes and diameters of all types of feed, holdback, and intermittent sprockets is essential to increasing the useful life of motion picture film. This future development demands and warrants the attention of the most competent engineers in the industry. Realization of these goals would materially increase production, decrease production costs, and produce an even better product.

As a note of caution, individualistic industry might misinterpret the purposes of standardization. Standardization does not mean that improvements are barred or limited; on the contrary, it does mean that only the best is used. Only proved recommended changes become formal standards. Individual capable management is still the secret of producing high-quality products. Nothing is taken from individual effort and ability; but, rather, individual effort and ability are given better tools with which to produce even better individualistic products. Standardization properly applied assures present stabilization with enterprise for the future.

The motion picture industry faces not only many problems that are common to other industries but it has also specific problems unto itself. The conservation of motion picture film attended with the conservation of all types of materials that are normally utilized in the production, distribution, and exhibition of motion pictures, necessitates that each and every one connected with the industry shall realize that full coöperation is essential for maintaining the high standards of entertainment expected by the public. The problems are upon us. It is in this spirit that the technical committees of the Society, on Cinematography, Color, Exchange Practice, Laboratory Practice, Non-Theatrical Equipment, Preservation of Film, Process Photography, Sound, Standards, Studio Lighting, Television, Theater Engineering, Projection Practice, Theater Design, Screen Brightness, and Theater Protection continue studying the procedures in their respective fields to assist the motion picture industry in solving the technical conservation and procedure problems as they arise. Much work has been done and published by these Committees on recommendations for Conservation of Film, Projector and Projection Room Design, Theater Design, and Theater Protection. Investigation and study are now in progress. Suggestions will be welcomed by these Committees and the Officers of the Society.

THE REMOVAL OF HYPO AND SILVER SALTS FROM PHOTOGRAPHIC MATERIALS AS AFFECTED BY THE COMPOSITION OF THE PROCESSING SOLUTIONS*

J. I. CRABTREE, G. T. EATON, AND L. E. MUEHLER**

Summary.—During processing, if photographic materials are insufficiently fixed and washed, the silver thiosulfates and sodium thiosulfate retained may result in staining of the non-image areas and fading of the image during subsequent storage. In the case of films and plates the thiosulfates may be removed completely if a judicious choice of hardening and fixing baths is made and if the most effective washing technique is employed but, with prints, traces of hypo are invariably retained which can be removed by subsequent treatment in a peroxide-ammonia solution.

Several factors contribute to the retention of sodium and silver thiosulfates and the extent of this retention was measured by careful determination of the residual thiosulfate and silver in the processed material. The hardening agent, potassium alum, used in hardening baths and fixing baths caused the greatest retention while chrome alum had little effect. The accumulation of silver during exhaustion of the fixing bath resulted in retention of silver thiosulfates.

The removal of sodium and silver thiosulfates was aided by (1) use of a second fixing bath to remove silver and (if non-hardening) to assist removal of hypo, (2) an increase in the pH of the fixing bath preferably above the isoelectric point of gelatin, (3) hardening prior to fixation as compared to hardening during or after fixation, (4) raising the temperature of the wash water, (5) increasing the pH of the wash water or by the use of a dilute ammonia solution near the end of the washing process. These treatments were less effective with photographic papers because of the high retention of thiosulfates by the paper base and the baryta coating. Processing recommendations to insure permanency during (a) archival and (b) normal periods of storage are given.

INTRODUCTION

When a photographic film or paper is insufficiently washed during processing, hypo together with silver thiosulfates is retained and, if the concentration is sufficiently great and the conditions of storage are appropriate, fading of the image results. In the case of film with

* Presented at the 1942 Fall Meeting at New York; received January 8, 1942. Communication No. 862 from the Kodak Research Laboratories.

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

nitrocellulose base, when exposed to high temperatures, nitrogen oxides may be liberated¹ and, in the presence of moisture, the resulting nitric acid reacts with the silver image causing fading.

In this paper the term "fading" refers to any change in the density or hue of the silver image which may or may not be accompanied by a staining in the highlights. The chief causes are: (a) sulfiding of the silver image by the sulfur present in the residual hypo,² and/or (b) the decomposition of residual sodium silver thiosulfate complexes which produces sulfiding of the image together with silver sulfide in the highlights.

The process of fixation consists in the conversion of the insoluble silver halides (chloride, bromide, or iodide) in the emulsion to soluble complex silver thiosulfates and the process of washing consists in the removal in solution of sodium thiosulfate together with a small proportion of silver thiosulfates.

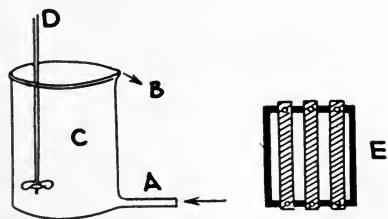


FIG. 1. Experimental washing apparatus.

The ultimate result of incomplete fixation and/or incomplete washing is the conversion of the silver present in the residual silver thiosulfate to silver sulfide by virtue of decomposition of the silver thiosulfate, or by reaction with hydrogen sulfide present in the atmosphere. The results of these reactions are

visible in the dense area of a film or print by reflected light as either a yellowish stain or a metallic luster and in the highlights as a yellowish to yellowish brown stain of silver sulfide.

In any consideration of washing, therefore, it is important to ascertain the concentration of both the residual silver ion and thiosulfate ion and to study the changes in the proportion of the two as washing progresses.

Most of the experiments outlined below were made with motion picture films but in general the results obtained apply also to other photographic films.

In order to determine the relative sensitivity of motion picture images to residual hypo, strips of various processed motion picture negative, positive, and sound-recording emulsions on safety type base, containing known quantities of hypo, were placed in a sealed glass vessel which contained water, and stored for several days in an

oven maintained at a temperature of 110°F. The strips were suspended on glass rods supported by glass frames and the condition of the film noted at definite intervals. These storage tests assisted in the determination of certain maximum permissible hypo concentrations (sodium thiosulfate crystal, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) with respect to fading for various types of materials. These maximum tolerable quantities were tentatively set at 0.05 milligram per square inch for coarse-grain negative, 0.01 milligram per square-inch for positive or fine-grain positive, and 0.005 milligram per square-inch for extremely fine-grain negative and positive films such as Microfile. With concentrations of residual hypo greater than these, indications of fading, especially in the halftones, were obtained under the extreme storage conditions used.

The relationship between accelerated fading tests and normal storage conditions has not been precisely determined. However, negative and positive motion picture films which have been stored at Kodak Park³ for at least ten years at 55°F and 70 per cent relative humidity and which contained quantities of hypo of the order of that in present-day commercially processed emulsions have not shown signs of visible fading. A period of one day in the accelerated test would therefore appear to be equivalent to a period of not less than ten years at a temperature of 55°F and 70 per cent relative humidity. For shorter times of keeping greater quantities of hypo than those stipulated may be tolerated.

In this connection it is of interest to know the approximate hypo and silver contents of some films and papers processed commercially. Many samples of films and prints from various sources have been tested during the past few years for hypo and silver content and the results shown in Table I indicate the existence of a wide variation in hypo content. In general the residual silver content was very low.

With the present trend toward the use of fine-grain emulsions for sound recording and projection print purposes, and the increasing use of fine-grain Microfile film for archival storage, it is of increasing importance that the hypo be removed from films as completely as possible during processing.

To date, although laboratory technicians have realized the importance of thorough washing it has been generally considered that the most important factors which influence the removal of silver and thiosulfate compounds are (a) time of washing, and (b) rate

of renewal of the water. The effect of the nature of the processing solutions has been given little consideration.

TABLE I

Average Hypo and Silver Contents of Some Commercially Processed Negatives and Prints

Film	Hypo (Mg per Sq-In)	Silver
Motion picture negative	Nil → 0.18	Nil → Trace
Motion picture positive	Nil → 0.18	Nil → Trace
Photofinishers		
(a) Machine processed	0.35 → 0.50*	About 0.01 mg per sq-in
(b) Hand processed	0.10 → 0.15*	Nil
X-ray	0.35 → 0.50*	Trace
Paper		
Single weight		
(a) Machine processed	0.15 → 0.35	Trace
(b) Hand processed	0.10 → 0.20	Trace
Double weight	0.25 → 0.45	Trace-0.01 mg per sq-in

* These films are coated on both sides and the data represent the concentrations of hypo in only one of the coatings. When the hypo content was determined by the mercuric chloride test, the total hypo content was measured and was, in each case, twice the value given.

Data in the literature regarding the effect of the composition of the processing baths on hypo removal are sparse and generally inconclusive. As early as 1900 Gaedicke⁴ stated that alum-hardened plates required excessive washing compared with non-hardened plates. In 1917 Lüppo-Cramer,⁵ commenting on Elsdén's⁶ use of neutral thiosulfate, reported that a highly acid non-hardening fixing bath washed out more slowly than plain thiosulfate. Hickman and Spencer⁷ in 1924 attempted to show the effect of hardening agents and modified fixing baths on the washing of plates. They investigated the use of alum and formaldehyde between the developer and fixing bath and the use of alum in the fixing bath. Formaldehyde had no effect on the time of washing, while immersion in a 5 per cent alum bath with adequate washing before and after "profoundly influenced the retention of electrolyte." When alum was used in a fixing bath maintained sufficiently acid to prevent subsequent hydrolysis, there was no difficulty in removing hypo or other electrolyte. In view of this apparent uncertain effect of alums on washing, it was considered desirable to make an extensive investigation involving various types of present-day processing solutions in order to deter-

mine the effect on hypo and silver removal of the use of various developers, stop baths, fixing baths, and supplementary treatments, and especially the effect of the presence of hardeners in the fixing bath, variations in the pH of the bath, the time of fixation, and the effectiveness of the subsequent washing procedure.

METHOD

At the outset it was realized that careful control of the various factors involved would not be obtained by the use of trays or large tanks, but a series of flat spiral reel outfits in use for the daylight processing of 35-mm films proved satisfactory and permitted adequate reproducibility of results.

One-foot lengths of the film were developed in 500 cc of the recommended developer, drained for 10 seconds, rinsed 10 seconds in running water, hardened and fixed for four times the apparent "time to clear" (see p. 25) in a 500-cc volume of the bath, drained 10 seconds, and finally washed in an experimental washing apparatus designed to give a very rapid change of water and a high degree of agitation as shown in Fig. 1. All the processing solutions and the wash water were maintained at a temperature of 68°F and uniform agitation was used throughout.

The water, which overflowed at *B*, was introduced through *A* into the 2-liter circular tank *C* at a controlled flow such that the outflow was 55 times the capacity of the vessel each hour. The agitation produced by the water influx was increased greatly by the use of a high-speed electric stirrer *D* having a slightly fluted convex disk for the stirring propeller. Samples of the processed film were mounted on a wooden rack *E* held in position in the tank. These conditions were such that high-speed negative films fixed in fresh baths, washed completely in 40 minutes following the most inhibitive treatment with respect to the removal of hypo. With positive films the flow was reduced to 12 gallons per hour or about two-fifths that used for negative film.

The majority of the tests were made with Eastman Motion Picture Super-XX Panchromatic Negative Film, Type 1232, but tests were also made with the following Eastman Motion Picture Films:

Plus-X Panchromatic Negative Film, Type 1231.

Background Panchromatic Negative Film, Type 1213.

Fine-Grain Panchromatic Duplicating Negative Film, Type 1203.

Release Positive Film, Type 1301.

High Contrast Positive Film, Type 1363.

Fine-Grain Duplicating Positive Film, Type 1365.

Sound Recording Film, Type 1357.

In addition, tests were made with Microfile, Type 5204, and paper prints.

Melting-point determinations were made on each sample of processed film to determine whether or not the degree of hardening was seriously affected by modifications of the fixing and hardening bath formulas.

The quantity of hypo retained by all the processed film samples was determined by the mercuric chloride-potassium bromide method of Crabtree and Ross⁸ in which one square-inch of film is placed in a 10-cc volume of the reagent* and the resultant turbidity compared with a series of standard turbidities. The latter are produced by the addition of measured volumes of a 1:10,000 solution of hypo to the 10-cc volume of the reagent.

Note: The fact that the total residual hypo in a film sample is accurately measured by the mercuric chloride reagent has been verified by two confirmatory tests: (1) when the film was washed just enough to give a negative test with mercuric chloride, a negative test was obtained with an excess of 1 per cent acidified silver nitrate solution which reacts with all the hypo *in situ*, and (2) when one-half of a film sample was soaked in water to equilibrium and the solution tested with mercuric chloride, an identical value was obtained as by direct determination on the other half of the film sample.

The quantity of hypo retained by prints was determined by bathing the print sample in a 1 per cent (acidified) silver nitrate solution, reacting the excess silver nitrate with sodium chloride, fixing out the silver chloride with hypo solution, and then determining the transmission density of the silver sulfide stain. The corresponding quantity of hypo was read from a standard curve.

The relative quantities of silver retained by the processed film samples were determined by the sodium sulfide spot test in which a drop of 0.2 per cent sodium sulfide solution containing 1 cc of 40 per cent formalin per 100 cc was placed on the film for 5 minutes and then removed with absorbent paper. The relative quantities were recorded as density readings ($D = \log 1/T$) obtained by measuring the percentage transmission of tungsten light through the silver

* For formula, see appended table of formulas.

KODAK FORMULAS

Constituents	Constituents in Grams per Liter										Crabtree-Ross, Hypo Test Solution			
	F-1	F-5	F-6	F-10	F-23	F-24	F-25	D-7	D-16	DK-60a		D-72*	D-76	SB-3
Sodium thiosulfate (hypo)	240.0	240.0	240.0	330.0	240.0	240.0	300.0							
Sodium sulfite (desiccated)	15.0	15.0	15.0	7.5	17.5	10.0	5.0	9.38	39.6	50.0	45.0	100.0		
Sodium bisulfite					25.0			0.46						
Acetic acid, 28%	48 cc.	48 cc.	48 cc.	70 cc.			10 cc.							
							glacial							
Boric acid, crystal		7.5					5.0							
Potassium alum	15.0	15.0	15.0	22.5			10.0							30.0
Chrome alum					32.0									
Kodalk			15.0	30.0					20.0					
Sulfuric acid, 5%														
Elon								0.46	0.31	2.5	3.1	2.0		
Hydroquinone									6.0	2.5	12.0	5.0		
Pyro								1.87						25.0
Potassium bromide								0.86	0.26	0.50	1.9			
Sodium carbonate								4.70	18.7	67.5		25.0		
Borax												2.0		
Citric acid									0.68					
Potassium metabisulfite									1.5					25.0
Mercuric chloride														
pH value	4.0	4.1	4.9	4.6	3.1	5.6	4.0	9.7	9.5	10.0	8.6			

* Dilute 1:2 for use.

sulfide spot when the transmitted light was picked up by a photoelectric cell, the output current of which was amplified and indicated on a microammeter.

The pH of solutions was determined with the Beckman Industrial pH meter standardizing with an acid phthalate buffer solution at $pH = 3.97$.

The relative quantities of silver in prints were determined by spot testing the emulsion side with 0.2 per cent sodium sulfide solution and visually judging the intensities of the silver sulfide stains.

A further check was made on the relative silver contents by subjecting samples of the prints to accelerated fading conditions (over water at 110°F) which caused the silver thiosulfate complexes to decompose to produce a silver sulfide stain.

The concentration of silver in fixing baths was determined by using the Argentometer described by Weyerts and Hickman.⁹

The relative rates of hypo and silver removal were determined for chrome alum (Kodak *F-23*), potassium alum (Kodak *F-25* or Kodak *F-5*), and non-hardening (Kodak *F-24*) fixing baths, and the effect of increasing pH in each case was studied. Two-bath combinations of these three types and modifications of them were also investigated.

The effect of a series of wetting agents upon the removal of both hypo and silver was also studied. The tests indicated that the use of wetting agents had no practical value in this connection.

EFFECT OF COMPOSITION OF PROCESSING BATH

(1) *Composition of the Developer.*—Tests made under the same conditions of rinsing, fixing, and washing with Kodak *D-76*, *DK-60a*, *D-72* (1:2), and *D-7* (pyro) developers showed that there were no differences in the rate of removal of hypo or silver from Super-XX Panchromatic Negative Film, Type 1232, when using the Kodak *F-5* fixing bath.

(2) *Composition of Stop Baths.*—Although acid stop baths are not invariably used when processing negative or positive films, a comparison between water, a 2 per cent solution of acetic acid, and a 3 per cent solution of chrome alum (Kodak *SB-3*) showed that none of these baths had any appreciable effect in retarding or hastening washing when the Kodak *F-5* fixing bath was employed.

(3) *Composition of Fixing Baths.*—Experiments by the authors with paper prints and roll films have shown that the use of a *fresh*

chrome alum fixing bath¹⁰ causes an increase in the rate of hypo removal as compared with the use of a fresh potassium alum fixing bath. This was clearly demonstrated when Plus-X Panchromatic Negative Film, Type 1231, was washed for 10 minutes in a vertical glass tube with different quantities of water flowing through the tube per unit of time. The quantity of residual hypo was plotted against the rate of flow as shown in Fig. 2, from which it is apparent that the rate of removal from chrome alum hardened film far exceeds that from potassium alum hardened film.

With a chrome alum fixing bath apparently the hypo is not so strongly held as in the case of potassium alum baths and is very

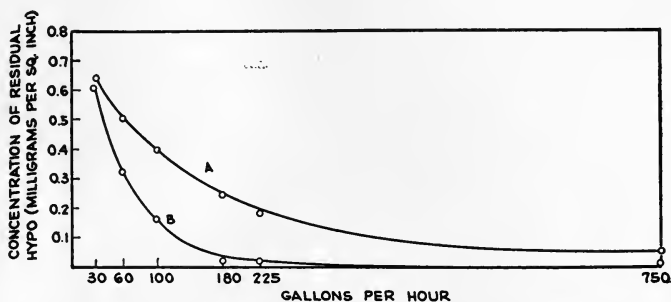


FIG. 2. Effect of rate of flow on rate of removal of hypo from A: film fixed in fresh potassium alum fixing bath (Kodak *F-25*); B: fresh chrome alum fixing bath (Kodak *F-23*). Eastman Plus-X Panchromatic Negative Film, Type 1231. Time of washing, 10 minutes.

readily washed from the film. The relatively thick Eastman Motion Picture Films, Types 1231 and 1232, when washed under the extreme conditions of 5 minutes in the experimental apparatus (Fig. 1) at 41°F, following the chrome alum fixing bath, retained only very small quantities of hypo.

The use of a non-hardening fixing bath (Kodak *F-24*) without pre- or supplementary hardening was slightly more effective than the use of a chrome alum fixing bath with respect to hypo removal but was impractical because of swelling of the emulsion and the tendency for reticulation. A non-hardening fixing bath is practical only when used in combination with a suitable hardening bath or with films which are sufficiently hardened in manufacture.

The variations in concentration of hypo in the fixing baths studied had no effect on the rate of removal of hypo from processed film.

Other ingredients (exclusive of alums) had no effect provided they did not change the pH of the bath.

Under the experimental conditions described on p. 13, the silver content of the washed film was essentially zero.

(4) pH of Fixing Baths.—The pH value of a fixing bath is significantly related to its composition which results from a consideration of sulfurization life, hardening properties, rate of fixation, exhaustion life, and sludging properties.^{10,11} Various fixing bath formulas therefore give different initial pH values as, for example,

Kodak *F-23*— $pH = 3.1$ —Chrome Alum

Kodak *F-5* — $pH = 4.1$ —Potassium Alum-Boric Acid

Kodak *F-10*— $pH = 4.6$ —Potassium Alum-Boric Acid

Kodak *F-6* — $pH = 4.9$ —Potassium Alum-Boric Acid

These baths were compared to determine whether or not a difference in initial pH affects the rate of elimination of hypo from film. It is considered that the slight differences in the chemical constituents of the potassium alum baths were unimportant as compared with the pH differences.

TABLE II

Effect of pH of Fixing Baths on Rate of Removal of Hypo (Eastman Super-XX 1232)

Time of Washing (Min)	Hypo Content (Mg per Sq-In)			
	<i>F-5</i> $pH = 4.1$	<i>F-10</i> $pH = 4.6$	<i>F-6</i> $pH = 4.9$	<i>F-23</i> $pH = 3.1$
10	0.20	0.12	0.02	0.02
25	0.08	0.06	Nil	Nil

The data show that with potassium alum baths the rate of removal of hypo is greatest with baths having a high pH value. It was also found that by adjusting the initial pH of a fixing bath to a higher or lower value by the addition of alkali or acid, a corresponding change in the rate of removal of hypo resulted, but this procedure may impair the optimum properties of the fixing bath. Although chrome alum baths have low initial pH values there is no appreciable retention of hypo after washing.

(5) Degree of Exhaustion of Fixing Bath: (a) *Effect of pH Change on Hypo Removal.*—The *F-23* chrome alum, *F-5*, *F-6*, and *F-10* potassium alum fixing baths were exhausted to approximately 500 feet per gallon with Eastman Super-XX Panchromatic Negative Film, Type 1232, and the pH , degree of hardening, and rate of removal of hypo determined at different stages of the exhaustion.

The film was developed in *D-76*, rinsed 5 seconds in running water, fixed for 20 minutes, and washed for 10 and 25 minutes in the experimental washing device shown in Fig. 1. In order to maintain constant the quantity of fixing bath lost by carry-over when the film samples were transferred to the washing apparatus, the films were first suspended until the residual fixing bath began to drain dropwise.

It was found that the slight increase in *pH* (approximately 0.5 unit) of the *F-5* fixing bath during exhaustion under these conditions was not sufficient to effect any appreciable change in the rate of removal of hypo. However, when the *pH* of *F-6* or *F-10* was increased by 0.5 unit, the hypo contents of the films decreased as shown below:

Time of Washing (Min)	<i>F-10</i> <i>pH-4.6</i>	<i>F-10</i> <i>pH-5.1</i>	<i>F-6</i> <i>pH-4.9</i>	<i>F-6</i> <i>pH-5.4</i>
10	0.12	0.02	0.02	Nil
25	0.06	Nil	Nil	Nil

The *pH* of the *F-23* chrome alum bath increased by 3 units. Removal was very rapid after fixation in chrome alum baths at the *pH* of the fresh solution and more rapid at higher *pH* values. It should be remembered that with chrome alum baths the initial hardening and non-sludging properties are retained for not more than 24 hours.¹⁰

If no rinse was used between development and fixation with *F-5*, the *pH* increased more rapidly and effected somewhat greater

TABLE III

Effect of Exhaustion of Fixing Baths on Rate of Removal of Hypo Comparison of "Rinse" and "No Rinse" Between Development and Fixation Eastman Super-XX Panchromatic Negative Film, Type 1232

Bath	<i>pH</i>	Hypo Content (Mg per Sq-In)	
		Wash, 10 Min	Wash, 20 Min
<i>F-5</i> , fresh unused	4.1	0.18	>0.04
<i>F-5</i> , exhausted to 400 ft per gallon with rinse	4.60	0.14	0.34
<i>F-5</i> , exhausted to 400 ft per gallon, no rinse	5.45	<0.005	<0.005
<i>F-5</i> , exhausted to 400 ft per gallon with rinse, <i>pH</i> adjusted	4.1	0.18	0.04
<i>F-5</i> , exhausted to 400 ft per gallon, no rinse, <i>pH</i> adjusted	4.1	0.18	0.04

changes in the rate of removal of hypo as shown in Table III. These pH effects were further verified when the pH of the exhausted baths was adjusted to the pH value of the fresh bath.

(b) *Effect of Silver Content on Removal of Silver and Hypo.*—As mentioned previously, the concentration of silver in the clear portions of the film is almost as important with respect to permanence as the residual hypo in the film. As is the case with hypo, if the storage

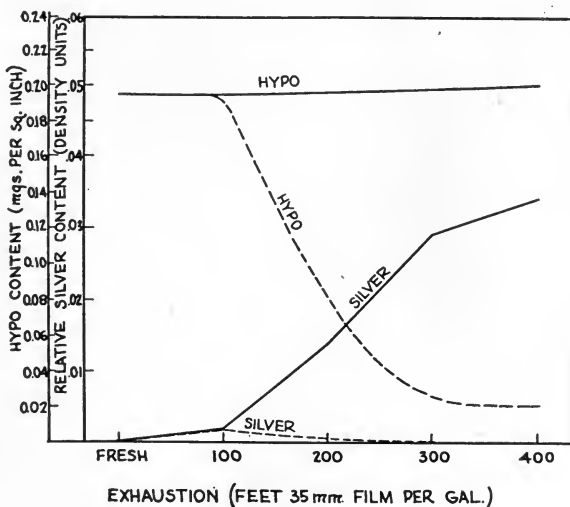


FIG. 3. Effect of exhaustion of fixing bath on hypo and silver content after washing. Eastman Super-XX Panchromatic Negative Film, Type 1232. Fixed in Kodak F-5. Washed 5 minutes at 68°F.

— pH of fixing bath maintained at 4.1.
 - - - pH of fixing bath increased with exhaustion to 5.5.

conditions with film or prints are favorable, the silver thiosulfate complexes are not particularly harmful in the absence of hydrogen sulfide in the air. However, if any unfavorable change occurs in these conditions, the complexes decompose to produce a yellow stain of silver sulfide which is proportional in intensity to the quantity of silver retained. A study was therefore made of the effect of the degree of exhaustion, the pH during exhaustion, and the degree of washing on the relative quantities of silver and hypo retained by the film.

Unexposed Eastman Motion Picture Super-XX Panchromatic

Negative Film, Type 1232, was developed as recommended and then fixed for four times the apparent "time to clear" (see "Time of Fixation," p. 25) in the Kodak *F-5* potassium alum fixing bath without the use of a rinse between development and fixation. The fixing baths used were both fresh and exhausted to 100, 200, 300, and 400 feet per gallon. Similar tests were made with Eastman Motion Picture Positive Film, Type 1301, and all tests with both emulsions duplicated in the Kodak *F-23* chrome alum fixing bath and in the Kodak *F-24* bisulfite-sulfite non-hardening fixing bath.

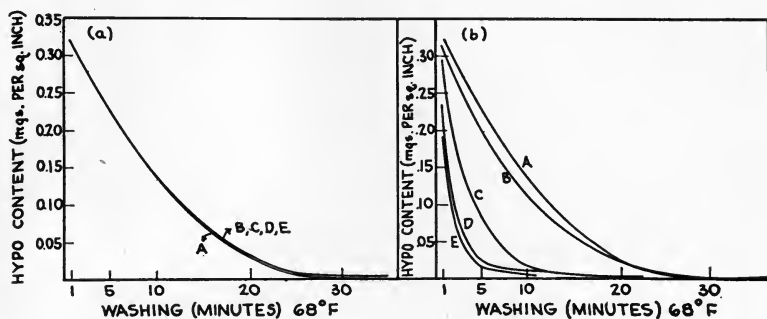


FIG. 4. Effect of exhaustion of fixing bath on rate of removal of hypo by washing. Eastman Super-XX Panchromatic Negative Film, Type 1232. Fixed in Kodak *F-5*.

Curve A—Fresh bath, $pH = 4.1$.

B—Exhausted to 100 feet per gallon, $pH = 4.3$.

C—Exhausted to 200 feet per gallon, $pH = 4.7$.

D—Exhausted to 300 feet per gallon, $pH = 5.1$.

E—Exhausted to 400 feet per gallon, $pH = 5.5$.

(a) pH maintained at 4.1.

(b) pH increased with exhaustion from 4.1 to 5.5 as shown above.

The curves in Figs. 3, 4, and 5 illustrate the effects of the degree of exhaustion and changes of pH of the *F-5* fixing bath on the rates of removal by washing of hypo and silver from processed Motion Picture Negative Film, Type 1232.

Fig. 3 illustrates two important relationships between the hypo and silver contents of the film after a given washing time of 5 minutes, namely:

(1) If the pH of the fixing bath was maintained during exhaustion at the pH of the fresh bath, the residual hypo content was essentially constant while the silver content increased appreciably.

(2) If the pH of the fixing bath was allowed to increase (4.1 to 5.5) by carry-over of developer during exhaustion, the residual

hypo content decreased to a low value and the silver was completely removed at pH values greater than 4.9, which is the isoelectric point of gelatin (see p. 43). The pH of the bath exhausted to 300 feet per gallon was 5.1.

Further experiments indicated that after a washing time of 30 minutes the hypo content was reduced to zero when the pH of the bath increased to 5.5, but when the pH was maintained constant at 4.1, the hypo content decreased to a certain small quantity not re-

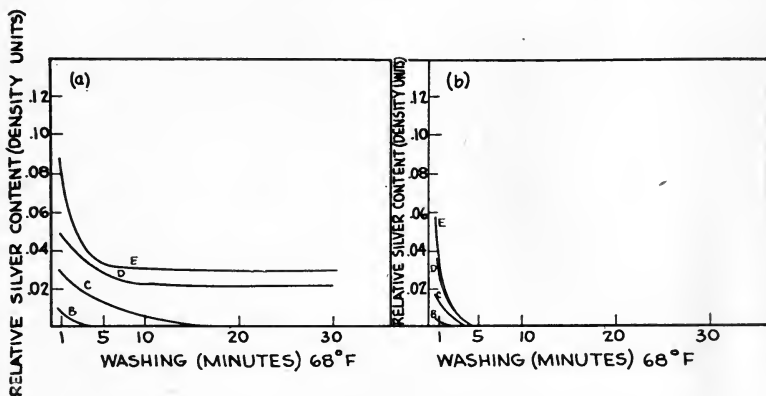


FIG. 5. Effect of exhaustion of fixing bath on rate of removal of silver by washing. Eastman Super-XX Panchromatic Negative Film, Type 1232. Fixed in Kodak *F-5*.

Curve *A*—Fresh bath, $pH = 4.1$.

B—Exhausted to 100 feet per gallon, $pH = 4.3$.

C—Exhausted to 200 feet per gallon, $pH = 4.7$.

D—Exhausted to 300 feet per gallon, $pH = 5.1$.

E—Exhausted to 400 feet per gallon, $pH = 5.5$.

(a) pH maintained at 4.1.

(b) pH increased with exhaustion from 4.1 to 5.5 as shown above.

movable by further washing. Silver was retained only after fixation in the baths exhausted to about 200 feet per gallon when the pH was maintained. The quantity of this residual silver after a 30-minute wash was approximately 20 per cent lower than after a 5-minute wash and remained constant even after two hours' washing.

These facts are substantiated in greater detail in Fig. 4. The curves in Fig. 4(a) and (b) indicate the relative rates of removal of hypo for increasing times of washing after fixation in baths exhausted to varying degrees (1) with the pH maintained, and (2) at increasing pH values in the range 4.1 to 5.5. An increase in pH

increased appreciably the rate of removal of the hypo but, after fixation in the baths exhausted to about 200 feet of 35-mm film per gallon and with the pH maintained, the hypo content could not be reduced entirely to zero by any amount of washing.

The curves in Fig. 5(a) and (b) show a similar effect of pH on the rate of removal of silver, namely, that above a degree of exhaustion of approximately 200 feet per gallon the silver can not be removed entirely by washing when the pH is maintained.

It is therefore apparent that after a certain degree of exhaustion, if the pH of the fixing bath is maintained constant, neither the hypo nor the silver is completely removable by washing. A study of the relative quantities of hypo and silver retained after fixation in baths exhausted to different degrees in the range from 250 to 500 feet per gallon showed that the retention of silver approximately paralleled that of the hypo.

The curves in Figs. 4 and 5 show that an increase in the pH of the fixing bath to a value above 4.9 permitted the complete removal of the hypo and silver. Complete removal may also be accomplished by bathing the film in an 0.03 per cent ammonia solution (1 cc of 28 per cent ammonia per liter) following washing of the film or by the use of a fresh second fixing bath as described later.

In general, similar results were obtained when a chrome alum fixing bath (Kodak *F-23*) was used. The hypo content decreased with time of washing much more rapidly than as indicated in Fig. 4, except for a small quantity retained by the film following fixation in exhausted baths, when the residual silver and hypo contents were somewhat less than those retained after fixation with exhausted potassium alum baths. However, prolonged washing removed some of the residual silver and hypo retained after chrome alum fixation but had little effect on that retained after potassium alum fixation when the pH of the bath was maintained.

With the bisulfite-sulfite non-hardening fixing bath, there was no retention of hypo or silver following any degree of exhaustion, and the hypo was removed somewhat more rapidly than after fixing with chrome alum baths.

Data from experiments with finer-grained and more thinly coated films, such as Eastman Motion Picture Release Positive Film, Type 1301, and Fine-Grain Release Positive Film, Type 1302, indicated that the same general effects were obtained but to a lesser degree than with the high-speed negative film, Type 1232. A factor

of four times the apparent "time to clear" was also used for the time of fixation with these films.

(c) *Effect of Original pH of Fixing Baths on Removal of Silver from Film.*—Figs. 4 and 5 show that complete removal of silver and hypo was possible when the pH of the *F-5* fixing bath was allowed to increase during exhaustion to values above 4.9. When the pH was maintained, the silver content of the film increased with exhaustion. Tests were made to determine the effect of the pH of different fixing baths, when maintained during exhaustion, on the silver retained.

The fixing baths used were *F-5* at pH = 4.1, *F-10* at pH = 4.6,

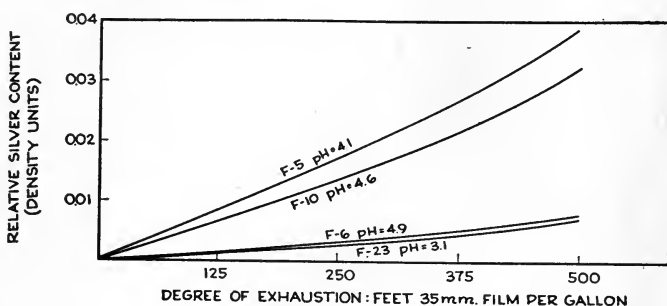


FIG. 6. Effect of fixing bath pH on retention of silver by films when original pH value is maintained during exhaustion. Eastman Super-XX Panchromatic Negative Film, Type 1232. Washed 20 minutes.

F-6 at pH = 4.9, and *F-23* at pH = 3.1 and these were exhausted to 125, 250, 375, and 500 feet of 35-mm Super-XX Panchromatic Negative Film, Type 1232, per gallon. The film strips washed for 20 minutes in the apparatus described in Fig. 1 were spot-tested with sodium sulfide and the transmission densities of the silver sulfide spots determined. The relative silver contents expressed in these density units were plotted against the degrees of exhaustion as shown in Fig. 6.

The curves show that less silver was retained as the pH of the bath increased from 4.1 to 4.9 and that somewhat less silver was retained by film fixed in an exhausted chrome alum bath.

(6) *Replacement of Sodium Thiosulfate with Ammonium Thiosulfate.*—Equimolecular (14.4%) and semimolecular (7.2%) concentrations of ammonium thiosulfate were substituted for the

sodium thiosulfate in the Kodak *F-5*, *F-23*, and *F-24* solutions and these baths compared with the regular formulas. The addition of ammonium thiosulfate to the baths increased the *pH* somewhat so that an adjustment to the *pH* of the regular baths was necessary.

With substitution in the *F-5* bath, washing tests indicated that after fixing in the 7.2 per cent ammonium thiosulfate bath the rate of removal of hypo was equal to that with the regular bath but, after fixing in the 14.4 per cent bath, the rate was approximately 30 per cent greater. No differences were measurable between sodium and ammonium thiosulfate in the case of the chrome alum (*F-23*) or non-hardening (*F-24*) fixing baths. With respect to silver, any differences were so small that they were not detectable by the sulfide test.

EFFECT OF VARIOUS FACTORS

(1) Time of Fixation.—Tests were made with developed Eastman Motion Picture Super-XX Panchromatic Negative Film, Type 1232, and Eastman Motion Picture Release Positive Film, Type 1301, in both fresh and exhausted sulfite-bisulfite (*F-24*), potassium aluminoboric acid (*F-5*) and chrome alum (*F-23*) fixing baths. The baths were exhausted to 125, 250, 375, and 500 feet per gallon with (*a*) the *pH* maintained at the *pH* of the fresh bath, and (*b*) the *pH* increased by carry-over of developer. The times of fixing used were 2, 4, 6, and 10 times the apparent "time to clear" in each bath. All test strips were washed for 15 minutes.

The "time to clear" of an emulsion is a somewhat variable factor and dependent upon (*a*) the nature and intensity of the incident light used to observe the clearing point (by refraction), and (*b*) the ability of the individual to judge the clearing point. It is particularly difficult to determine in the case of exhausted fixing baths because of the very low rate of conversion of the halides to soluble complexes. For these reasons the term "apparent time to clear" was preferred.

The most satisfactory method of viewing was to direct a beam of tungsten light between the film and a black background at an angle of approximately 45 degrees to the background. The most accurate "time to clear" determination required uniform agitation such that the conversion of the halides was uniform over the entire emulsion area. Relative clearing and fixing times should be determined at a fixed temperature, for example, 68°F.

Under average darkroom conditions the results were usually within 5 per cent when uniform agitation was employed and, although tungsten light provided the best lighting conditions, the light from a Series *0A*, *1*, or *3* safelight, although less intense, did not alter the "apparent time to clear" when transmitted rather than reflected.

Since the removal of the last traces of residual silver is necessary for archival purposes, tests were made with the *F-5* fixing bath and the negative film, Type *1232*, to determine the best time of fixing

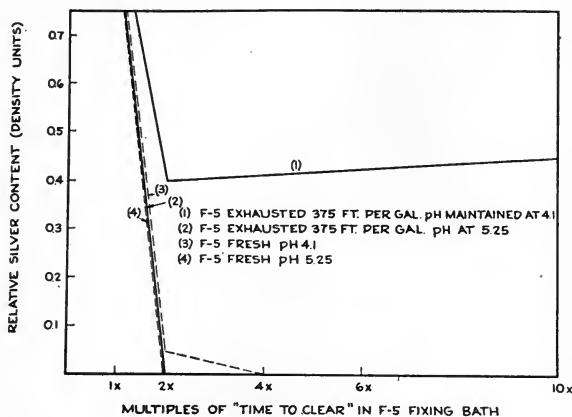


FIG. 7. Effect of increasing time of fixation on the residual silver content of film with fixing bath pH maintained at 4.1; with fixing bath pH at 5.25. Kodak Fixing Bath *F-5*. Eastman Super-*XX* Panchromatic Negative Film, Type *1232*.

to accomplish this. The fresh fixing bath at $pH = 4.1$ was compared with the fresh bath adjusted to $pH = 5.25$, with exhausted *F-5* at $pH = 5.25$, and with exhausted *F-5* adjusted to $pH = 4.1$. The curves in Fig. 7 show that (a) either a fresh or exhausted bath at a pH above 4.9 permits the removal of the last traces of silver from the negative film after fixing for twice the apparent "time to clear" and (b) a fresh bath at its original pH (4.1) required four times the apparent time to clear in order to make complete removal of the last traces of silver possible, but an exhausted bath when adjusted to pH 4.1 or to any value below 4.9 caused the retention of a considerable quantity of silver. Similar results were obtained with the

positive film, Type 1301, except that the quantities of silver retained were somewhat less.

The actual difference in the quantities of silver retained after fixing for twice and four times the "time to clear" in the *F-5* fixing bath at $pH = 4.1$ is admittedly small and may be of no practical significance. However, since removal by washing of the last traces of silver was desired, a fixing time of four times the apparent time to clear was used in both fresh and exhausted baths throughout this investigation.

When the times of fixing were extended to six and ten times the apparent "time to clear," the Super-XX Negative film, Type

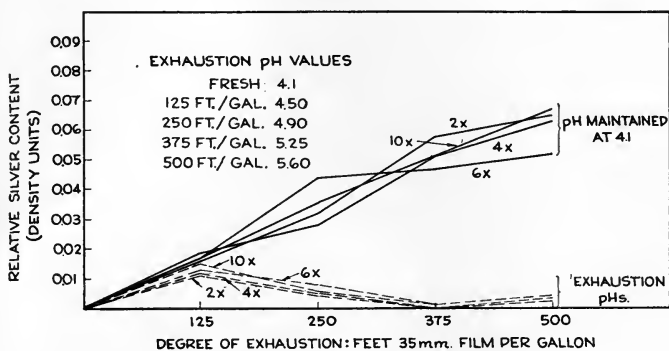


FIG. 8. Silver retained after increasing times of fixation in exhausted baths. Kodak Fixing Bath *F-5*. Film washed 15 minutes. Eastman Super-XX Panchromatic Negative Film, Type 1232.

1232, retained an almost constant quantity of silver after fixing in an exhausted bath with the pH maintained at 4.1, as shown in Fig. 7, but retained no silver when the pH was greater than 4.9.

It was of interest to determine the extent of the retention of silver at various stages of the exhaustion life of a fixing bath when the pH was maintained at 4.1 and when it was allowed to increase by addition of "carry-over" developer. The data and curves for tests made with Eastman Super-XX Negative Film, Type 1232, are given in Fig. 8 in which the relative silver contents are plotted in density units obtained by reading silver sulfide spots as previously described. Three facts are evident, namely, (a) when the pH was below 4.5, the silver retained increased with exhaustion, (b) when the pH of the baths reached 4.9, the silver content was almost zero and at pH

= 5.25 no silver was retained, which verifies the data illustrated in Figs. 4 and 5, and (c) there was very little variation in the quantity of silver retained after fixing for times longer than four times the time to clear.

The curves in Fig. 9 illustrate the results of similar experiments made with Eastman Motion Picture Release Positive Film, Type 1301. Three facts are evident from these curves, namely, (1) when the pH during exhaustion was allowed to increase to 4.9 only a very minute trace of silver remained in the sample fixed for ten times the apparent "time to clear," (2) when the pH was main-

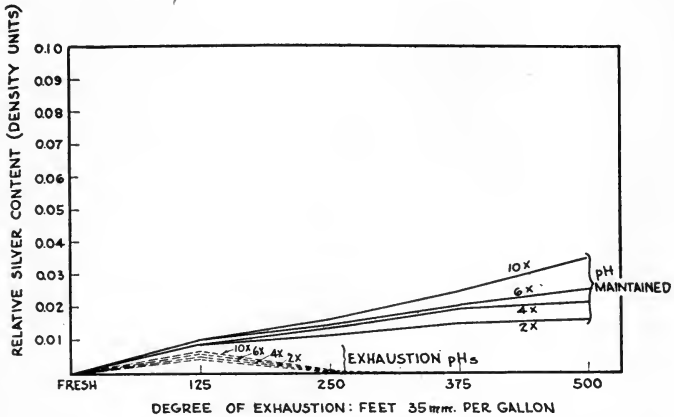


FIG. 9. Silver retained after increasing times of fixation in exhausted baths. Kodak Fixing Bath F-5. Film washed 15 minutes. Eastman Positive Film, Type 1301.

tained below 4.9 the silver content increased with exhaustion but the absolute quantities were less than those retained by Super-XX Negative Film, Type 1232 under the same conditions, and (3) with the pH maintained below 4.9 the quantity of silver retained increased somewhat with the longer times of fixation for a given degree of exhaustion.

With the Release Positive Film, Type 1301, the quantity of residual silver increased somewhat after extended times of fixing (for example, from 2 to 10 times the apparent time to clear) but no such increase occurred with the Super-XX Negative Film, for similar multiples of the apparent time to clear. The actual time in minutes in the

fixing bath and the relationship of this time to the degree of hardening of the film should explain this anomaly.

The apparent time to clear in fresh *F-5* was approximately 30 seconds for the Release Positive Film, and 3 minutes 15 seconds for the Super-XX Negative Film. Therefore, four and ten times the time to clear the films, Release Positive and Super-XX Negative, in fresh and exhausted *F-5* baths were:

		Release Positive Type 1301	Super-XX Negative Type 1232
Fresh bath	4×	2 Min	13 Min
	10×	5 Min	32½ Min
Exhausted bath	4×	4 Min	26 Min
	10×	10 Min	65 Min

The degree of hardening produced in an *F-5* fixing bath increased from about 150°F to near the maximum in 1 to 10 minutes and reached the maximum in about 20 minutes (Fig. 10). It is believed that the gelatin-hardener complex is responsible for the retention of the silver and that as the degree of hardening increases the retention of silver increases provided the *pH* of the bath is below 4.9. This would suggest that the quantity of residual silver does not increase with Super-XX Negative Film, because the maximum degree of hardening is obtained in four times the apparent time to clear in a fresh bath. However, it can increase with Release Positive Film because the degree of hardening increased rapidly during the periods of "four" and "ten" times the "time to clear."

Thus, from the standpoint of residual silver, extended times of fixation in potassium alum baths at *pH*'s below 4.9 have no advantage especially in exhausted or partially exhausted baths. To remove the silver completely, the use of multiple fixing baths must be considered.

When a fresh chrome alum (*F-23*) or fresh bisulfite-sulfite (*F-24*) fixing bath was used, the rate of removal of hypo was so great as compared with the rate when a potassium alum fixing bath (*F-5*) was used that all of the hypo was removed in approximately 10 minutes following any time of fixation up to 30 minutes.

After fixation in exhausted chrome alum baths for the recommended times, both silver and hypo as a complex were retained by the film in approximately the same ratio and quantity as following fixation in a potassium alum bath. However, with prolonged

fixation in exhausted chrome alum baths there was no increase in the quantity of retained silver thiosulfate complex.

(2) *Use of Two Fixing Baths.*—Several combinations of fixing baths were studied to determine the effect on the rate of removal of hypo, the degree of hardening, and the rate of elimination of the silver from the processed film. A potassium alum hardening fixing bath (Kodak *F-5*) was used as the first bath and either (a) a non-hardening bath *F-24* ($pH = 5.6$), (b) a non-hardening bath, *F-5* without alum ($pH = 4.5$), or (c) a chrome alum bath *F-23* used as the second bath.

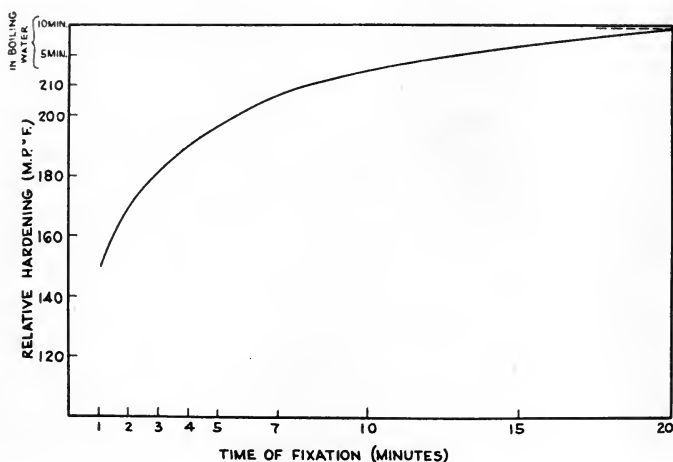


FIG. 10. Effect of time of fixation on degree of hardening. Eastman Motion Picture Positive Film, Type 1301. Kodak *F-5* Fixing Bath (fresh pH ; 4.1).

When emulsion 1232 was fixed in each of these fixing bath combinations, the residual hypo content in the film varied considerably for a given washing time as shown in Table IV. A time of 20 minutes in the first bath (to insure a maximum degree of fixation in the exhausted baths) and 5 minutes in the second bath was employed.

TABLE IV

Effect of Second Fixing Bath on Rate of Removal of Hypo

Time of Washing (Min)	Hypo Content (Mg per Sq-In)				
	<i>F-5</i>	<i>F-5:F-5</i>	<i>F-5:F-5</i> (No Alum)	<i>F-5:F-24</i>	<i>F-5:F-23</i>
10	0.20	0.20	0.02	0.005	0.06
25	0.05	0.04	Nil	Nil	Nil

The *F-5* (no alum), *F-24*, and *F-23* combinations with *F-5* increased the rate of removal of hypo greatly but the two baths of *F-5* were no different from *F-5* alone. The degree of hardening was equal in the *F-5* and the *F-5:F-5* combination but increased somewhat with exhaustion when using the *F-5* followed by the *F-23*. The hardening was decreased slightly when using *F-5* followed by *F-24*.

When exhaustion studies of the *F-5:F-24* combination were made it was found that the *F-24* bath began to sludge after the bath was only half exhausted. This difficulty was overcome (a) by using an intermediate water rinse, (b) by using the *F-5* fixing bath with the alum omitted as the second bath, or (c) by lowering the pH value of *F-24* from 5.6 to 4.5 by the addition of acetic acid. When (c) was employed the rate of removal of hypo was the same as with the *F-5:F-5* (no alum) combination. In this manner sludging did not occur during the exhaustion life of the bath.

The use of *F-6* as a second bath was very effective for hypo removal, the hypo content of the film being 0.04 milligram per square-inch after 10 minutes' washing. However, with this combination (*F-5:F-6*) it was necessary to maintain the pH of the *F-6* bath at 4.9 to 5.5 or its effectiveness would be lost because of a lowering of the pH by the carry-over of the more acid *F-5* fixing bath.

The silver content of the film was essentially reduced to zero throughout the exhaustion when a second fixing bath was used for 2 to 5 minutes after the first *F-5* fixing bath, regardless of the composition of the second bath.

It has been shown that when the degree of exhaustion of a single bath (pH maintained) exceeded 200 feet of 35-mm. film per gallon, silver was permanently retained by the film even after prolonged washing. A second fixing bath should therefore be used and may be exhausted to the point where silver is permanently retained by the film.

When the pH of the first bath was maintained during exhaustion the pH of the second bath did not change appreciably, but if the pH of the second bath was low (e. g., *F-5* at pH = 4.1) the degree of exhaustion was limited by the silver retained by the film. On the other hand, if the pH of the second bath was above pH = 4.9, the degree of exhaustion was limited only by other factors such as sludging properties.

The relationship between the quantities of silver in the fixing

bath and the silver retained by Eastman Super-XX Negative Film, Type 1232, is shown in Fig. 11 when two *F-5* fixing baths were used with the *pH* maintained at 4.1. It is apparent that the silver content increases very rapidly in the first bath from the start of the exhaustion and increases rapidly in the second bath only after 500 feet per gallon have been fixed. The silver content of the film increased rapidly after fixation in the first bath, but following the second bath, the content was zero until 250 feet per gallon were

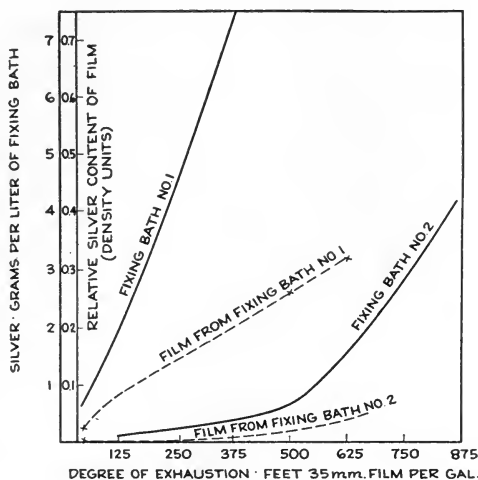


FIG. 11. Effect of exhaustion on concentration of silver in first and second fixing baths and in film fixed in these baths. Eastman Motion Picture Super-XX Panchromatic Negative Film, Type 1232. Kodak Fixing Bath *F-5*. *pH* maintained. Film washed 15 minutes.

fixed when it began to increase. The exhaustion life of this combination of baths is dependent upon the proposed use of the processed film.

The use of any single bath or combinations of baths which have *pH* values higher than $pH = 4.9$ prevents the retention of silver.

(3) *Effect of Separated Hardening and Fixing.*—A study was made of the removal of hypo and silver when the hardening and fixing operations were performed in separate baths. Negative film, Type 1232, was hardened in a potassium alum bath which was essentially *F-5* without hypo for 10 minutes and then fixed in fresh

F-5 without alum for 10 minutes.* These operations were then reversed and a comparison made with an emulsion processed (1) in *F-5* and (2) with a chrome alum hardening stop bath (*SB-3*) in combination with a bisulfite-sulfite non-hardening fixing bath (*F-24*).

The analyses indicated that in the case of potassium alum hardening baths hardening should take place before fixation to obtain the best conditions for effective hypo removal. The most effective combination was the chrome alum hardening bath (*SB-3*) followed by the bisulfite-sulfite non-hardening fixing bath but this combination was no better than the use of a chrome alum fixing bath (*F-23*) alone. However, tests with shorter times of washing in a less effective washing system than that illustrated in Fig. 1 showed that the *SB-3*: bisulfite-sulfite fixing bath combination was more effective than *F-23* alone. When exhausted fixing baths were used, the retention of silver paralleled that of the hypo.

(4) *Temperature of Processing*.—The results of several experiments with various films indicated that for a fixed washing temperature large temperature differences between the developer or fixing bath and the wash water resulted in only small differences in the rate of elimination of hypo and no differences in the rate of elimination of silver.

WASHING

(1) *Effect of Nature of Water*: (a) *pH of the Wash Water*.—The pH of the wash water has a very definite effect upon the rate of removal of hypo as shown in Table V. Eastman Fine-Grain Release Positive Film, Type 1302, was developed, fixed, and washed for 5 minutes at 65°F in tap water at a pH of approximately 7.0, and then further washed by bathing in trays of water at different pH values.

TABLE V

Effect of pH of Wash Water on Rate of Removal of Hypo (Potassium Alum Fixing Bath)

pH	Concentration of Hypo (Mg per Sq-In)	
	2 Min Washing	5 Min Washing
3.4	0.13	0.07
5.4	0.09	0.05
8.0	0.04	0.02
10.0	Nil	Nil

* Formulas of this type are necessary because those similar to the non-hardening *F-24* fixing bath sludge when only one-half exhausted.

It is seen that an increase in pH of the wash water caused a decrease in the time required to eliminate a given quantity of hypo from a given emulsion. This fact is of practical importance, especially where an alkaline water supply is used, and is contrary to the claims of D. K. Allison¹² that washing with water adjusted to the isoelectric point of the gelatin will produce the most efficient hypo removal, but it substantiates the results of Sheppard and Houck.¹³

The most convenient and useful alkali for this purpose is ammonia. In an experiment comparing the treatment of film in ammonia after fixation in a potassium alum bath with fixation in a chrome alum bath, the results showed that the ammonia treatment has an effect equal to that of chrome alum in permitting hypo removal. Super-XX Negative Film, Type 1232, was fixed in *F-25*, rinsed for 2 minutes, bathed in 0.03 per cent ammonia solution ($pH = 10.2$, and washed with film samples fixed in *F-25* and in the chrome alum *F-23* bath. The results are given in Table VI.

TABLE VI

Effect of Dilute Ammonia Bath After Fixing on Hypo Removal

Fixing Bath	Treatment	Hypo Content (Mg per Sq-In)		
		5 Min	15 Min	30 Min
Potassium alum (<i>F-25</i>)		0.56	0.24	0.08
Potassium alum (<i>F-25</i>)	0.03% Ammonia	Nil	Nil	Nil
Chrome Alum (<i>F-23</i>)		0.005	Nil	Nil

When film samples were washed in the same apparatus with the pH of the water maintained at approximately $pH-9.5$, the rate of removal was almost as great as indicated in Table VI.

TABLE VII

Effect of Ammonia on Degree of Hardening (Emulsion 1232)

Concentration of Ammonia (%)	Melting Point ($^{\circ}F$)		
	2 Min Bathing	5 Min Bathing	10 Min Bathing
0.56	161	140	100
0.28	174	166	126
0.14	182	176	154
0.07	186	182	172
0.03	194	192	190
0.00	210	210	210

The hardness of the gelatin film is affected by this alkaline treatment but not to any serious extent if the concentration of alkali is not excessive. From Table VII it is seen that ammonia used

at the concentration recommended (0.03%) is entirely satisfactory, at least for times of treatment up to 10 minutes.

(b) *Temperature of Wash Water.*—Previous studies on the removal of hypo by washing have shown that the rate of removal increases appreciably as the temperature of the wash water increases.² The curves in Fig. 12 for Eastman Motion Picture Super-XX Panchromatic Negative Film, Type 1232, are representative of the curves for

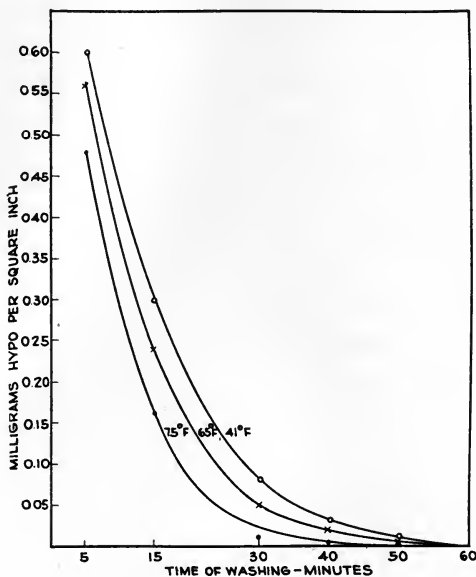


FIG. 12. Effect of temperature on rate of removal of hypo. Eastman Motion Picture Super-XX Panchromatic Negative Film, Type 1232.

the entire series of films tested. It is evident that an increase in the washing temperature produced an increase in the rate of removal of hypo from the film and that the effect is greatest for the shorter washing times. For example, an increase in temperature of the wash water from 41° to 75°F doubled the rate of removal of hypo for a 15-minute washing time, the actual quantity being reduced from 0.32 mg per sq-in to 0.16 mg per sq-in. Such differences in the rate of removal are of practical significance, especially where the available time for washing is short and the temperature of the water supply is low.

(c) *Chemical Constituents in Water.*—The degree of purity of the water supply is of primary importance when washing photographic materials for archival purposes because it is obviously useless to treat photographic images in water containing chemicals which are harmful to the image.

Distilled water, rain water, or water from melted ice or snow is satisfactory. Many city water supplies are suitable but their composition should be checked carefully before use. The most common impurities in water may be grouped as follows:¹⁴

(1) Dissolved salts which produce hardness such as bicarbonates, chlorides, and sulfates of calcium and magnesium. These are not dangerous from the standpoint of effect on the image but as a visible scum which reduces the transparency of the film. It is important, therefore, to squeegee the film thoroughly just previous to drying.

(2) Suspended matter which may consist of mud, iron rust, free sulfur, decayed vegetable matter, or biological growths. These should be removed by filtration.

(3) Dissolved extracts which are usually colored yellow or brown. Such coloring matter often becomes mordanted to the film or paper which has been hardened with alum causing stains but this staining may frequently be overcome by fixing in a non-hardening fixing bath free from alum.

(4) Dissolved gases such as air, carbon dioxide, and hydrogen sulfide. Waters containing hydrogen sulfide are also apt to contain colloidal sulfur which is retained by the film and ultimately reacts with the image.

(2) *Effect of Turnover of Water.*—A good washing system was a prerequisite to this investigation and, although no detailed consideration of the mechanics of washing is included here, it seemed advisable to consider in a general way the factors involved in washing in order (a) to insure the most effective washing conditions in an experimental washing device, and (b) to establish the general conditions to be satisfied in practice. The rate of renewal of water at the surface of the material being washed has been claimed an important factor.

The turnover is dependent upon the input of water and the dimensions of the vessel. In very small washing units, such as small diameter tubes, very shallow tanks, *etc.*, the turnover, with sufficient input, provides adequate agitation for the body of liquid. It is practical to use an input great enough to provide both turnover

and agitation. On the other hand, in large tanks, the agitation that can be produced by inflow usually is negligible, giving rise to a more or less stagnant condition in parts of the liquid.

It is apparent that the renewal of water at the surface of, say, a strip of film can be made adequate in the small washing units by using sufficient input but in the large tanks only by the use of mechanical agitation.

During the removal by washing of hypo from photographic products the rate of diffusion of hypo from the film to the water depends on the difference in concentration of hypo in the film and in the water. The rate of washing is therefore greatest when the concentration of hypo in the water is at a minimum, while the rate can be zero when the concentration in the water is sufficiently great.

In order to obtain the greatest rate of washing as indicated above, it is important to employ maximum turnover and maximum rate of renewal at the film surface.

The experimental washing device used in this investigation fulfilled the conditions outlined. The turnover was 55 times the capacity per hour and the agitation was sufficient to overcome stagnation. A decrease in input increased the time required to remove a given amount of hypo from the film but the turnover and degree of agitation were always adequate.

Curve *A* in Fig. 2 demonstrates the effect of different "inputs" on the removal of hypo from 15-inch strips of 35-mm film in a given washing time when suspended in a vertical glass tube of 1½-inch diameter. This system was characterized by the fact that the turnover caused adequate agitation and that renewal at the surface approached a maximum.

Samples of Eastman Motion Picture Release Positive Film, Type 1301, and Super-XX Panchromatic Negative Film, Type 1231, were processed and, after fixing, were washed in tanks of large volume as compared with the tube described above. At a given input the tests were duplicated with and without air agitation, the results indicating that air agitation of the wash water greatly increased the rate of removal of hypo owing to the rapid renewal of water at the surface of the film.

A third system considered was spray washing. Since in this case no contaminated water could accumulate on the film, it was evident that maximum turnover, agitation, and renewal at the

surface were approached. The tests indicated that such a system was very effective in the removal of hypo.

WASHING OF PAPER PRINTS

Photographic paper prints, even after careful processing, are more susceptible to deterioration (*i. e.*, fading) than film negatives or positives. Two factors influence this apparent susceptibility, namely, (1) the high degree of reflection of the print reveals very slight changes in the silver image, and (2) the structure of the print is such that more hypo is retained per unit area than by an equivalent area of film following the same fixing and washing procedure.

The hypo contents of commercially processed prints vary considerably depending upon the type of washing equipment used but, in general, they contain quantities indicated in Table I.

An earlier paper² discussed in detail the removal of hypo following fixation in fresh fixing baths and it was recommended that, in order to insure the complete elimination of hypo, single- and double-weight prints be washed for one-half hour to one hour, respectively, in water at 60° to 70°F and then be treated in a hydrogen peroxide-ammonia eliminator.

The effect of exhaustion of the fixing bath on the removal of silver and hypo was not considered, although the silver thiosulfates retained in the print are largely responsible for the yellowing of the highlights of faded prints. The experiments outlined above for film were therefore repeated with photographic paper and it was found that the removal of the last traces of hypo and silver from prints is more complicated than in the case of films. In general, photographic papers consist of (1) the paper base, (2) a baryta coating, and (3) an emulsion coating, all of which retain hypo and silver.

Regular photographic papers were compared with a paper having the base and baryta coating waterproofed and coated with a chloride type of emulsion. The results showed that both hypo and silver were more readily removed from such a waterproofed paper by washing than from the regular paper, indicating that the normal baryta coating and paper base tend to retain a considerable quantity of hypo and silver.

Experiments with non-waterproofed paper base alone bathed in plain hypo, fresh and exhausted, showed that for a given washing time the quantity of hypo and silver remaining in the paper base increased with the time of treatment in the hypo bath and that

the last traces of hypo and silver could not be removed by washing. With a potassium alum bath (*F-5*), more hypo was retained than with a non-hardening bath (*F-24*). This difference was not due to the presence of alum but to the difference in pH of the two baths, as evidenced by the fact that the hypo content was the same when *F-5* was compared with *F-5* minus alum and adjusted to the same pH . Ammonia baths caused an increase in the rate of removal but an excessive time of treatment was necessary to bring about complete removal.

Baryta coatings on both regular paper base and on glass were tested. With the "paper plus baryta," more hypo was retained than with the paper base alone. To determine the role of the baryta, coatings on glass were compared with gelatin coatings on glass.

In a plain hypo solution the baryta coating retained hypo which was not readily removed by washing. When a potassium alum fixing bath was used, a much greater quantity of hypo was retained by the baryta which could not be removed by prolonged washing, but the increased hypo retained under the same conditions by the plain gelatin was washed out. Both the baryta and gelatin coatings retained hypo and silver from an exhausted fixing bath when the pH was maintained, but when the pH increased during exhaustion to 5.5 the baryta retained slightly less hypo and silver while the gelatin did not retain any. It is apparent, therefore, that the removal of hypo and silver from baryta is not affected by changes in the pH of the fixing bath in the range 4.0 to 5.6 to the same degree as the removal from gelatin.

A dilute ammonia solution, however, promoted the removal of hypo and silver from either the baryta or the gelatin coatings while a second fixing bath removed the silver.

The presence of potassium alum in the fixing bath and changes in pH of the fixing bath effected similar changes in the rate of removal of hypo from the paper emulsion coated on the waterproofed base (with baryta coating) as obtained with Eastman Motion Picture Positive Film, Type 1301.

When the regular paper base plus baryta plus emulsion (regular photographic paper) was treated in non-hardening (*F-24*) and hardening (*F-5*) fixing baths both at the original and increased pH values, it was found that (1) pH values in the range of 4.0 to 5.6 had little effect on the rate of removal of hypo and silver, (2) the rate

of removal was greater after fixing in *F-24* as compared with *F-5*, only during the early stage of washing, and (3) small amounts of residual hypo and silver in the base and baryta coating were not removed by very prolonged washing. Adsorption of silver commenced with the first paper prints processed.

Bathing in ammonia solutions caused the complete removal of hypo and silver from photographic paper only after very long times of treatment and, therefore, could not be considered adequate in the normal processing of prints.

When residual silver is mordanted it is apparently always combined with a certain amount of thiosulfate. If these silver complexes remain in the print, especially in the absence of excess hypo, early decomposition to silver sulfide may result. This condition may exist even after the hypo has been removed with the hypo eliminator² because, following fixation in a moderately exhausted bath, the hypo eliminator does not attack the silver complex as readily as it does hypo. With increasing times of treatment in the eliminator the quantity of residual hypo and silver decreases until eventually they are completely removed but such treatment is usually too severe for the finished print.

The most practical and efficient method of removing the last traces of both silver and hypo from prints is to employ two or three successive fixing baths. A second bath is imperative in any fixing operation and a fresh third bath is imperative in the preparation of permanent prints when the residual silver content must be zero. The residual hypo is then removed by means of the hypo eliminator.

In the case of films, as shown in Fig. 11, silver was retained in the film (with exhaustion) when the fixing bath or baths were maintained at a *pH* value below 4.9 but was not retained if the *pH* was higher than 4.9. A similar study made with prints indicated a retention of silver (to a lesser degree) when the baths were maintained below *pH* = 4.9 but, at *pH* values above 4.9, the nature of the fixing bath had very little or no effect on the removal of silver from the prints. Fig. 13 shows the relative increase in the silver content of the baths and prints when two *F-5* fixing baths at *pH* = 4.1 were used. It is evident that sixty to seventy 8 × 10-inch prints per gallon can be processed free of residual silver by using this combination of fixing baths.

In general, the effects of (1) the change of *pH* of the fixing bath, (2) the use of a dilute ammonia solution, and (3) the combinations

of fixing baths recommended for the removal of silver and hypo from film were of little practical value with prints because of the mordanting effects of the baryta coating and paper base. However, chrome alum fixing baths, which may be used if the resulting slight green stain can be tolerated, and plain hypo baths provide conditions for a very marked increase in the rate of removal of hypo and silver by washing. This increase in the rate of removal is obtained, however, only during the first few minutes of washing. With exhausted chrome alum baths traces of both silver and thiosulfate remain after prolonged washing of prints as in the case of films.

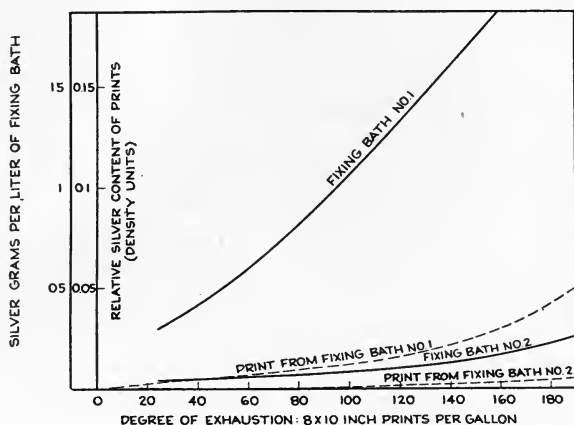


FIG. 13. Effect of exhaustion on concentration of silver in first and second fixing baths and in paper prints fixed in these baths. Azo *F-3*. Kodak Fixing Bath *F-5*. pH maintained. Prints washed 20 minutes.

THEORETICAL DISCUSSION

When silver halides are fixed out from an emulsion by a sodium (or ammonium) thiosulfate (hypo) fixing bath, they are undoubtedly converted to complex silver thiosulfates, the exact composition of the complexes varying with the degree of exhaustion of the bath. The work of Bassett and Lemon,¹⁵ using silver nitrate solution, would indicate that the maximum ratio of silver to sodium in the complex formed in sodium thiosulfate solutions rich in silver is represented by the formula $\text{NaAg}_3(\text{S}_2\text{O}_3)_2$. On the other hand, Baines,¹⁶ using silver carbonate, found that the formula of the complex in thiosulfate solutions rich in silver is $\text{NaAg}(\text{S}_2\text{O}_3) \cdot \text{H}_2\text{O}$.

References are cited by Baines to show the general agreement by other workers on the composition of this complex.

Assuming that the initial ratio of silver to sodium in the complex approaches a value of 3:1 or 1:1, this ratio is quickly changed by virtue of dilution by the excess fixing bath diffusing through the emulsion.

Much of the published literature states that the first reaction is to form a difficultly soluble complex and that on prolonged fixation this is changed to a more soluble one. However, it is now apparent that when the milkiness of a pure silver bromide emulsion has disappeared, the silver halide has been rendered completely soluble and capable of being washed out.

This removal of silver complexes takes place in two stages, namely, (1) the complex silver ions diffuse out of the gelatin film while in the fixing bath, and (2) diffusion of both complex silver ions and thiosulfate ions takes place in the wash water.

The washing of photographic materials represented by (2), above is considered to be an exponential process provided there are no impediments to normal diffusion of the hypo from the gelatin layer. Hickman and Spencer⁷ reported a divergence from the exponential curve, or a "tailing off" of the curve, when a potassium alum hardening bath was used prior to fixation, and stated that potassium alum retards the washing out of an electrolyte (not identified).

The washing data in this investigation, when plotted logarithmically, verified the exponential process and the "tailing off" of the curves in some cases. When potassium alum fixing baths were used the divergence from the exponential was very marked but with chrome alum baths, no "tailing off" occurred. However, with exhausted potassium and chrome alum baths appreciable "tailing off" occurred as a result of the retention of a complex silver thiosulfate ion.

With photographic papers the divergence from the exponential was always large because of the effect of the baryta coating and the paper base.

The primary concern in this study was the removal of the last traces of thiosulfate and silver thiosulfate ions (which caused the "tailing off" of the exponential washing curves) retained by the material even after long times of washing.

The retention of very small quantities of hypo and silver which in some cases are not removed by prolonged washing is undoubtedly

the result of adsorption of the thiosulfate and silver ions. Gelatin as an amphoteric electrolyte does not combine with salts but with ions. At pH values lower than the isoelectric point ($pH = 4.9$) the gelatin becomes more positively charged and has a greater attraction for anions, such as the thiosulfate ion or a complex silver thiosulfate ion, while the converse is the case at pH values greater than the isoelectric point when the attraction diminishes for anions but increases for cations.¹³ The conditions under which thiosulfate and complex silver thiosulfate ions are adsorbed and the conditions for their subsequent removal by washing are outlined in Table VIII.

(1) Adsorption of Thiosulfate and Silver Thiosulfate Ions.

—The adsorption is governed by the following factors:

(a) *The pH of the Wash Water.*—Since the pH of the wash water is usually above 7.0, it is evident that the pH of a film fixed in any fixing bath at a pH lower than the isoelectric point will slowly approach the isoelectric point of the gelatin during washing, thus permitting a greater rate of removal of adsorbed anions such as thiosulfate ions. The higher the pH of the fixing bath the greater will be the apparent rate of removal because there is less ion adsorbed by gelatin from the higher pH fixing baths.

(b) *The Composition, Degree of Exhaustion, and pH of the Fixing Bath.*—With fresh potassium alum-boric acid fixing baths, the time required to remove completely the thiosulfate ion was much longer than with non-hardening baths but an increase in the pH of the fixing bath to $pH = 5.0$ produced an apparent increase in the rate of removal of the thiosulfate ion.

Assuming that the hardening of gelatin by alum is due to the precipitation of alumina or a compound with gelatin which will be termed an "alumina complex," it is apparent that this complex adsorbs thiosulfate ion in considerable excess over the amount adsorbed by gelatin alone.

With used potassium alum-boric acid hardening fixing baths, the last traces of thiosulfate and silver were not washed out when the pH was maintained ($pH = 4.1$ with *F-5*) but were easily removed when the pH increased to about 5.0 during the exhaustion. These results would tend to indicate that the silver and thiosulfate were adsorbed together as a negatively charged complex ion which washed from the film when the pH was sufficiently high. The fact that this complex ion was not removed by extended washing at low pH values,

TABLE VIII

The Adsorption and Subsequent Removal of Ions from Processed Photographic Film and Paper

Type of Fixing Bath	Mordanted Ion	Means of Removal
Potassium alum baths, <i>e. g.</i> , <i>F-5, F-10, F-25</i>		
(a) Fresh	$S_2O_3^{2-}$	(1) Increase temperature of wash water and agitation of water (2) Increase pH of fixing bath to value above isoelectric point of gelatin, <i>e. g.</i> , use <i>F-6</i> (3) Use dilute ammonia solution (0.03%)
(b) Exhausted	$[Ag_x(S_2O_3)_y]^{n-}$	(1) Increase pH above isoelectric point, <i>e. g.</i> , use <i>F-6</i> (2) Use any second or third fixing bath
	$S_2O_3^{2-}$	(1) Use a second fixing bath with pH above isoelectric point, <i>e. g.</i> , <i>F-6</i> (2) Use a second fixing bath minus potassium alum
Chrome alum baths, <i>e. g.</i> , <i>F-16, F-23</i>		
(a) Fresh	None	
(b) Exhausted	$[Ag_x(S_2O_3)_y]^{n-}$	(1) Increase pH of bath to value above 5.0 (no hardening at this value) (2) Use a second or third fixing bath; chrome alum or <i>F-24</i>
	Paper	
Bisulfite hypo, <i>e. g.</i> , <i>F-24</i>		
(a) Fresh	$S_2O_3^{2-}$	(1) Increase temperature of wash water (2) Increase agitation of prints in water (3) Peroxide-ammonia hypo eliminator
(b) Exhausted	$[Ag_x(S_2O_3)_y]^{n-}$	(1) Any second or third fixing bath followed by (2) Hypo eliminator
Chrome alum baths	As with <i>F-24</i>	As with <i>F-24</i>
Potassium alum baths		
(a) Fresh	As with <i>F-24</i> but much greater quantities	As with <i>F-24</i>
(b) Exhausted		

whereas thiosulfate ion alone was removed (as with a fresh bath), would suggest a difference in the mechanism of the adsorption of plain thiosulfate ions as compared with silver thiosulfate ions when adsorbed to the alumina complex.

The complex silver thiosulfate ion was adsorbed from baths at constant pH below $pH = 4.7$ only if the degree of exhaustion corresponded to a value of at least 200 feet of motion picture negative film per gallon. Since the composition of the sodium silver thiosulfate complexes in a fixing bath undoubtedly varies with the degree of exhaustion, it is quite likely that for degrees of exhaustion above the 200 feet per gallon stage the composition of the fixing bath is such that it can no longer affect the complexes in the emulsion sufficiently to prevent the adsorption of a complex silver thiosulfate ion by the alumina hardening complex. This contention is supported by the fact that any adsorbed complex is removed completely with a fresh hypo solution. If the degree of exhaustion and, therefore, the concentration of silver in the bath increases, it can be assumed that the degree of adsorption of silver to the alumina complex increases and likewise that the rate of diffusion of silver from the gelatin decreases.

Whether or not the composition of the adsorbed complex silver thiosulfate ion changes with increasing degrees of exhaustion is not known but preliminary analyses have indicated that up to a degree of exhaustion corresponding to 500 feet of Eastman Motion Picture Panchromatic Negative Film, Type 1232, per gallon, the ratio of silver to thiosulfate in the residual adsorbed complex ion is probably one silver atom to one thiosulfate radical.

When comparing the adsorption properties of chrome alum with potassium alum-hardened gelatin, in the case of a fresh fixing bath having a low or negligible silver content, the thiosulfate ion is apparently not mordanted to the chromium hardening complex but is very appreciably adsorbed to the alumina complex. However, when the silver concentration in the fixing bath reaches a critical value corresponding to a degree of exhaustion of 200 feet of the Negative Film, Type 1232, per gallon, traces of silver and thiosulfate are adsorbed both by the chromium and alumina complexes. After chrome alum fixation the silver and thiosulfate concentrations decrease on prolonged washing but remain constant after potassium alum fixation, unless the pH of the fixing bath or wash water is increased. These facts would indicate a difference in the mechanism

of adsorption of the thiosulfate ion, $[\text{Ag}_x(\text{S}_2\text{O}_3)_y]^{-n}$. With non-hardening fixing baths (*F-24*), both silver and thiosulfate likewise wash out more readily when the pH is allowed to increase as compared with a maintained pH of 5.6.

(c) *The Time of Fixation*.—An emulsion is considered completely fixed when it is possible to reduce the non-developed silver content to zero by subsequent washing. With Eastman Motion Picture Release Positive Film, Type 1301, on prolonged washing, it was possible to remove the silver completely after fixing for the "time to clear" but a much shorter washing time was adequate if the film was fixed for the usually recommended twice the apparent "time to clear" in a *non-hardening* fixing bath. However, when a potassium alum fixing bath was used complete fixation was obtained only after three to four times the apparent time to clear.

Exhaustion of a plain hypo bath (*F-24*) extended the washing time but exhaustion of potassium alum baths prevented complete fixation even when the "time to clear" factor was much greater than two. An increase in the pH of the fixing bath, however, facilitated washing.

On the other hand, films such as Eastman Motion Picture Super-XX Panchromatic Negative Film, Type 1232, containing silver iodide, required a factor of four times the "time to clear" followed by a washing time longer than was previously thought necessary for the complete removal of silver. An increased pH was also necessary when using exhausted potassium alum fixing baths to obtain complete fixation.

When fixing times of four to ten times the "time to clear" were used with Eastman Motion Picture Positive Film, Type 1301, and Super-XX Negative Film, Type 1232, in fresh and exhausted potassium alum fixing baths, two facts were evident, namely, (1) the quantities of residual hypo and silver in the Positive Type 1301 film increased appreciably, and (2) no measurable increase in the quantities of residual hypo and silver occurred with the Super-XX Negative Film, Type 1232.

These effects are closely related to the effect of time of fixation on the degree of hardening of the gelatin film. As the degree of hardening increases with time, the concentration of alumina in the gelatin increases and this, in turn, adsorbs an increasing quantity of thiosulfate ion or of a complex silver thiosulfate ion depending upon the condition of the bath.

The hardening of gelatin by chrome alum is more rapid than by potassium alum. The fact that no further adsorption of complex silver thiosulfate ion occurred on prolonged fixation would also indicate that maximum hardening was attained in a relatively short time.

It has been suggested that the silver image, in some cases, may retain small amounts of hypo even though the highlights are free from hypo. Most developed images on film and paper contain a trace of silver sulfide which is approximately proportional to the silver density and is revealed as a yellow residual image on treatment of the silver image with Farmer's reducer.^{17, 18, 19} Silver sulfide under certain conditions is known to be a mordant for certain dyes but experimental evidence has indicated that hypo is not mordanted. The sensitive mercuric chloride test for film and the quantitative determination of reducible sulfur in print images have failed to reveal any difference in the amounts of hypo retained by the non-image and maximum density areas of film or print images.

(2) *The Desorption of Thiosulfate and Silver Thiosulfate Ions.*—The adsorption of the silver thiosulfate complex may be reversed in several ways, namely, (a) by raising the pH of the fixing bath or wash water or both, and (b) by immersing the film in a fresh fixing bath in which the silver-ion concentration is very low or equal to zero.

Adsorbed thiosulfate ion is removed by raising the pH of the fixing bath or wash water, or both. The effect of the pH increase is probably to change the nature of the electrical charges on the adsorbent and to release the attraction between the ions and the adsorbent.

The results obtained with photographic papers may also be explained, for the most part, on the basis of an assumption of adsorption of both thiosulfate ion and complex silver thiosulfate ion.

In the case of the emulsion layer, the explanation for the retention of hypo and silver by film is directly applicable. However, additional sorption occurs in the baryta coating, both thiosulfate ion and complex silver thiosulfate ion being sorbed, but the changes in pH , effective for the removal of these ions from either gelatin, the alumina-gelatin hardening complex, or chrome alum-gelatin complex, were not great enough to reverse the sorption of the ions.

This was accomplished only after bathing in ammonia solutions for long times.

The hydrogen peroxide-ammonia hypo eliminator has a twofold effect on thiosulfate ions adsorbed to papers, namely, (a) the high pH of the solution causes desorption, and (b) the desorbed ion is oxidized to sulfate which is harmless. However, the adsorbed silver complexes do not respond as readily to pH change, as mentioned above, while there is probably a slow reaction between the adsorbed ion and the peroxide-ammonia solution. These silver complexes, however, are very readily desorbed in hypo solutions.

TABLE IX
Suggested Maximum Permissible Concentration of Hypo

Films	Commercial Use (Mg per Sq-In)	Archival Use (Mg per Sq-In)
Eastman Motion Picture Films		
Fine-Grain Duplicating Positive Film, Type 1365	0.02	0.005
Fine-Grain Release Positive Film, Type 1302	0.05	0.01
Super-XX Panchromatic Negative Film, Type 1232	0.20	0.05
Photofinishers and Amateurs	0.15-0.25*	0.05
Eastman X-Ray Films		
No screen	0.40-0.50*	0.10
Blue brand	0.25-0.40*	0.05
Industrial type A	0.15-0.25*	0.05
Prints		
Double Weight	0.20-0.25	Nil
Single Weight	0.10-0.15	Nil

* The coatings on many of these films consist of either (a) emulsion on one side and gelatin on the opposite side, or (b) emulsion on both sides (x-ray). The above data represent the hypo content of the coating on only one side of the film so that when employing the mercuric chloride test which determines the total hypo, the values in the above table should be doubled.

PRACTICAL RECOMMENDATIONS

In view of the increasing use of fine-grain films and the greater realization of the necessity for the perpetuation of photographic records, very careful attention should be given to the operations of fixing and washing.

If long life of the photographic image is not required, it is un-

necessary to remove the last traces of silver and hypo, so that in practice we may have two requirements, namely, (1) commercial fixing and washing for materials with an expected keeping life of a few decades or less, and (2) "archival" fixing and washing which implies complete removal of all substances which might affect either the image or non-image areas during long-time storage.

TABLE X

*Suggested Maximum Permissible Concentrations of Silver
pH of Fixing Bath Maintained below 4.9*

Single Bath

Films	Commercial Use	Archival Use
(a) Fixing Bath	1.5 grams per liter (twenty-five 8 × 10-inch films per gallon)	0.2 gram per liter (two 8 × 10-inch films per gal)
(b) Film	0.01 mg per sq-in	Nil
Paper		
(a) Fixing Bath	0.3 gram per liter (thirty 8 × 10-inch prints per gal)	0.05 gram per liter (five 8 × 10-inch prints per gal)
(b) Paper	0.005 mg per sq-in	Nil

Two Fixing Baths

Films		
(a) Fixing Bath No. 1	6.0 grams per liter (sixty to seventy 8 × 10-inch films per gal)	3.5 grams per liter (forty 8 × 10-inch films per gal)
Fixing Bath No. 2	0.5-1.5 grams per liter	0.2 gram per liter
(b) Film	0.01 mg per sq-in	Nil
Paper		
(a) Fixing Bath No. 1	2.0 grams per liter (two hundred 8 × 10-inch prints per gal)	0.80 gram per liter (seventy 8 × 10-inch prints per gal)
Fixing Bath No. 2	0.3 gram per liter	0.05 gram per liter
(b) Paper	0.005 mg per sq-in	Nil

Since the future history of a processed negative or print is unknown, it is always advisable to remove completely all residual thiosulfates. It is, however, quite possible that slight tolerances may be permissible even with archival films but this is not definitely known. At the present state of our knowledge, the maximum tolerances in the hypo and silver content of films and prints for

archival and commercial purposes given in Tables IX and X are suggested. The tables also show the suggested maximum permissible silver concentrations in the fixing bath or baths. This is important because the concentration of silver in the bath is an indication of the amount of silver likely to be retained by the film or print following good washing.

It is evident from Table X that archival films and prints should contain no residual silver to insure that the non-image areas remain clear indefinitely. However, a slight general yellow stain does not necessarily impair the usefulness of a film or print so that for commercial purposes a slight quantity of residual silver can be tolerated.

Two general types of photographic paper prints should be considered, namely, (1) the fine-grain chloride type contact paper and (2) the coarser-grain bromide type enlarging paper. The residual hypo content of commercially processed fine-grain prints should not exceed the values given in Table IX, but a somewhat greater quantity of residual hypo (approximately 50 per cent greater) may be tolerated in the bromide type prints because the coarser-grain images are not so susceptible to fading as the fine-grain images.² In the case of coarse-grain bromides for archival purposes, 0.05 to 0.10 milligram of hypo per square-inch could probably be tolerated. This hypo content may be obtained without the use of a hypo eliminator if the prints are washed for two hours in water at about 70°F and with optimum agitation. It must be remembered that other factors² influence the permanence of negatives and prints and these have been considered when establishing the tolerances given above.

The processing recommendations given below, when carefully followed, should effect the complete removal of silver and hypo from films or plates. The complete removal of silver and hypo from paper prints is always advised and complete hypo removal may be accomplished by the use of the peroxide-ammonia hypo eliminator² in addition to the recommendations given below. However, for those whose equipment is not adequate to meet these demands, appreciable improvement over their existing methods of processing can be effected by:

- (1) Use of two or more fixing baths to reduce the silver content.
- (2) Judicious choice of fixing baths to reduce both silver and hypo contents.
- (3) Adjusting the temperature of the wash water to 65° to 70°F to accelerate washing.

(4) Use of more intensive agitation as with compressed air.

The quantities of residual hypo and silver indicated in the tables are readily obtained under good fixing and washing conditions in the usually recommended times of washing and, so far as we know, can be considered to be safe, from a permanence viewpoint, if the films and prints are to be stored under *average conditions in temperate climates*. Under tropical or accelerated conditions, it is necessary to remove all the silver and hypo because films and prints containing amounts of hypo much less than those given may fade.

The term "commercial washing" has been used to denote the degree of washing necessary to insure these maximum quantities of hypo in both films and prints.

(1) *Tests for Silver and Hypo*.—Satisfactory tests for the presence of silver and hypo in film and paper are outlined below. These have been modified slightly from the methods outlined on p. 14 in order to meet commercial requirements.

(a) *For Silver*.—A drop of 0.2 per cent sodium sulfide is applied to the margin of the dry or squeegeed film or print and removed after 2 to 3 minutes by careful blotting. Any coloration produced by formation of silver sulfide in excess of a just visible cream tint indicates the presence of silver in the film or paper. For careful control a satisfactory standard is made by processing a blank sheet of film or paper through two fresh fixing baths and a control test made on this sheet. The stain produced is an indication of the stain that might be formed in the highlights with adverse storage conditions.

(b) *For Hypo*.—Many tests have been proposed in the literature for the determination of hypo in both films and prints. The potassium permanganate drip test is in common use for testing films and prints during washing but its sensitivity is limited and it does not determine the residual hypo in the washed material.

The mercuric chloride test described on p. 14 is very satisfactory for use with either dry or wet film samples but it is necessary to clip off a small piece of the film to be tested and it is not recommended for measuring the total hypo content of prints. This test is particularly useful when films are being prepared for archival storage. This reagent is poisonous, should be handled carefully, and washed down the drain with water when discarded.

An iodine spot test has been suggested²⁰ which is dependent upon the time required for the starch-iodine spot to decolorize. The

difficulty in application of the test was the reproducible measurement of the volume of reagent used for the "spot" which must be constant.

The silver nitrate test is extremely sensitive and especially suited to the measurement of hypo in prints. The spot-testing technique is used but the accuracy of the test does not depend upon the volume of reagent because the silver nitrate and hypo react *in situ* to produce a definite quantity of silver sulfide since a great excess of silver nitrate is used. The color of the spot varies from light yellowish brown to dark brown depending on the hypo content. The test may be used:

(1) To determine whether or not a print is entirely free from hypo following the use of the peroxide-ammonia hypo eliminator, when the procedure recommended in a previous paper may be used.² A dry print or an extra wet print may be spot-tested on the back with silver nitrate and, if no hypo is present, no yellow stain should appear. The excess water should be removed from a wet print before making the test.

(2) To determine the approximate quantity of residual hypo by matching the spot with one of a series of spots prepared on single- and double-weight prints having known hypo contents.

(2) The Fixing Process.—Complete fixation is necessary to insure complete removal of both silver and thiosulfate even though the washing system is efficient, and therefore the photographer needs to know (a) what bath or baths insure rapid removal of hypo and silver thiosulfate complexes in subsequent washing, (b) how long the photographic material should be fixed, and (c) when the baths should be discarded.

(a) *Choice of Baths.*—It has been shown that the use of single fixing baths having *pH* values* lower than 4.9 retards, to a considerable degree, the removal of residual hypo and silver complexes during subsequent washing.

On the other hand, when the *pH* of a fixing bath is above the isoelectric point of gelatin (*pH* = 4.9), no silver is retained by the processed film after washing, irrespective of the composition of the fixing bath, and the hypo is removed more rapidly during washing provided fixation is complete. It is desirable, therefore, to employ,

* The *pH* of fixing baths may be determined either with glass electrode *pH* meters, appropriate indicator solutions, or indicator test papers which may be obtained from chemical apparatus supply houses.

whenever possible, fixing baths at pH values in the range 5.0 to 5.5. A consideration of the fundamental properties of fixing baths showed that potassium alum fixing baths containing boric acid or a salt of the acid such as Kodak *F-5*, *F-6*, *F-10*, and *F-25* could be adjusted to pH values in the range 5.0 to 5.5 without changing the tendency to scum, the sludge life, the sulfurization life, or the degree of hardening. However, certain conditions must be fulfilled before their use at these pH values is practical, namely:

(1) An acetic acid rinse bath must be used following development (a) to dissolve calcium sulfite scum from the film, particularly when low pH developers have been used, and (b) to prevent the pH of the fixing bath from increasing to a value at which sludging and a lower degree of hardening may occur. Potassium alum-boric acid baths are sufficiently buffered to neutralize the acetic acid introduced into the bath.

(2) It may be necessary to use a quick rinse following fixation to avoid the formation of sludge in the wash water. This precipitation is usually evident only during intermittent processing and may be overcome by increased water flow and the use of the smallest possible tank. Squeegees used following the fixing procedure are very helpful.

Of the four baths considered, the *F-6* bath approaches this desirable pH range as can be seen from the following initial pH values:

$$F-5 \text{ — } pH = 4.1$$

$$F-10 \text{ — } pH = 4.6$$

$$F-25 \text{ — } pH = 4.2$$

$$F-6 \text{ — } pH = 4.9$$

The pH of the *F-6* bath is at the isoelectric point of gelatin and when this bath is used only a minute trace of silver is retained while hypo is very rapidly removed during washing. *F-6*, therefore, is invaluable in the removal of silver and hypo when used either as a single bath or as a second bath in a two- or three-bath combination.

As a result of the gradual addition of developer to a fixing bath during use, the pH value increases so that, even in the case of the *F-5*, *F-10*, and *F-25* baths (when used with normally alkaline developers and without an acid rinse bath or only a short water rinse), a point is soon reached when they are as satisfactory as *F-6* from a hypo and silver retention standpoint. Beyond this point the hardening properties continue to diminish so that it is desirable to maintain the pH at this value (about 5.0) by replenishment with acid.

Although chrome alum fixing baths and hardening baths also have advantages with respect to the removal of hypo and silver, the *F-6* bath is almost as effective in this connection and has less tendency to scum and sludge while it does not lose its hardening properties with age.

With this important general recommendation in mind, recommendations of other fixing baths and fixing bath combinations are given below for (1) continuous recirculating systems, and (2) non-circulating systems.

(1) *Continuous Recirculating Systems*.—The use of a single fixing bath, rather than two, in continuous recirculating systems such as are used in many motion picture processing laboratories is entirely practical because the hardening properties and the acidity (pH) are maintained by replenishment, while the silver content is kept at a minimum (approximately 1.0 gram per liter) by continuous electrolytic or sulfide recovery methods. The increasing iodide content of these baths, especially when using high-speed negative materials, does not seriously affect the retention of residual silver by the film. The iodide content usually is such that it does not alter the fixing time appreciably. Several different fixing baths are suitable for use in these systems, namely:

(A) A chrome alum bath similar to Kodak *F-23* is the most favorable because hypo is more readily removed after fixation in a chrome alum bath than with potassium alum baths and no supplementary treatments are necessary. The successful use of these chrome alum baths is possible, however, only by careful adherence to correct procedure as follows:

The baths should be revived periodically to maintain the chrome alum concentration while the pH should be held between values of 3.5 and 4.0. When used intermittently, chrome alum baths should be replenished immediately after use to prevent sludging.

Chrome alum baths tend to lose their hardening properties with age even without use, while an excessive amount of alkali carried over from the developer will tend to produce a greenish scum of chromium hydroxide on the film or a sludge in the bath.¹⁰ These sludging or scumming difficulties may be prevented by (I) the use of squeegees between developer and fixing bath, (II) by adequate replenishment, and (III) by maintaining the pH of the baths constant by the addition of sulfuric acid. Suitable methods of maintaining the pH of chrome alum baths have been described in the

article "New Stop Baths and Fixing Bath Formulas and Methods for Their Revival" (*J. Soc. Mot. Pict. Eng.*, XXXVIII (April, 1942), p. 353.

(B) A potassium alum bath of the type of *F-5* or *F-6* may be used. *F-5* at $pH = 4.1$ requires a subsequent treatment of the film for at least 3 minutes in an 0.03 per cent ammonia solution near the end of the washing operation in order to insure complete hypo removal. However, when *F-6* at $pH = 4.9$ or *F-5* modified to a pH of 5.0 to 5.5 is used, the ammonia treatment is not necessary.

With some potassium alum baths, particularly *F-6*, the alum of the fixing bath carried into the wash water tends to hydrolyze, resulting in sludge formation. This may be prevented by using either a spray washer or a narrow tank (to insure rapid removal of water) just prior to the passage of the film into the regular washing system.

(C) A non-hardening bath containing sulfite and bisulfite ($pH = 5.6$) may be used, followed by washing, and then hardening in an alkaline formaldehyde solution,* and washing provided the processing temperature is maintained at 68°F or lower in order to prevent excessive swelling in the baths.

(2) *Non-Circulating Systems (No Continuous Silver Recovery)*.—When a single fixing bath is used at a pH below 5.0 there is an accumulation of silver on exhaustion and, in order to be sure that no silver will remain in the final product after fixation in a partially used bath, it is imperative to employ at least two separate fixing baths in succession. By this means silver thiosulfates not removable by washing are taken out of the film and in addition the time of fixation may be reduced (see below, "Time of Fixation"). Although many combinations of fixing baths are possible, the following are suggested:

(a) Use of two bisulfite-sulfite non-hardening fixing baths in succession such as Kodak *F-24*, followed by washing and then hardening in the above formalin solution. The processing temperature must be maintained at 68°F or lower to prevent excessive swelling.

(b) Use of two potassium alum hardening fixing baths similar to Kodak *F-6* at $pH = 4.9$, followed by thorough washing.

(c) Use of two potassium alum hardening fixing baths similar to Kodak *F-5* at $pH = 4.1$, followed by thorough washing. The

* 10.0 cc of 40% formalin per liter plus 5 grams of sodium carbonate.

film is then immersed in an 0.03 per cent ammonia solution for 3 to 5 minutes and then washed for 5 to 10 minutes.

(d) Use of a potassium alum-boric acid bath, similar to Kodak *F-5*, *F-6*, or *F-25*, as the first bath, followed by the first bath with the alum omitted. When the second bath is transferred to the first tank for use as the first bath, as described below, it is necessary to add hardener. Besides removing silver thiosulfate, the non-hardening second bath causes more rapid removal of hypo and prevents the possible formation of alumina sludge in the wash water.

(e) High-temperature processing demands the use of chrome alum baths which may be employed in the following combinations: a chrome alum hardening bath (*SB-4*) followed by a non-hardening fixing bath (*F-24*), or two chrome alum fixing baths (*F-23*).

To insure the complete removal of residual silver, the non-hardening bath used in (a) should be discarded when it is half exhausted with respect to silver content, otherwise two fixing baths should be used in combination with the chrome alum hardening bath. The half-exhaustion point is determined by the method described on p. 58.

(b) *Time of Fixation: (1) Single Bath "Time of Fixation."*—When the pH of a fixing bath is greater than 4.9, silver is not retained by the film and the usually recommended time of fixing of twice the "time to clear" is satisfactory as shown in Fig. 7. However, when the pH is maintained below 4.9 it has been shown that the use of a single bath is not practical because considerable quantities of silver are retained by the film. Chrome alum fixing baths cannot be used above $pH = 3.8$ to 4.0 because of sludging and loss of hardening properties. Thus, with pH maintained below 4.9 it is necessary to use at least two fixing baths in order to remove completely the silver by washing.

(2) *Time of Fixation with Two Fixing Baths.*—Apart from being impractical, the long times of fixation required in an exhausted single bath with pH below 4.9 caused increased retention of silver thiosulfate complexes by the film. A second fixing bath removes the residual complexes retained from the first bath and permits a shorter time of fixing in the first bath. The times given below are based upon exhausted first baths and are not variable if the complete removal of silver is desired.

For the present-day high-speed negative materials a minimum time of 10 minutes (approximately twice the "time to clear" in an exhausted bath) is recommended in the first bath and a minimum

time of 3 minutes in the second bath at 68°F. Minimum times of 5 and 3 minutes, respectively, are suggested for positive type emulsions. These times were arrived at from a consideration of the minimum time to obtain (a) complete fixation, and (b) adequate hardening.

Shorter times of fixation than those given produce a low degree of hardening with the alum fixing baths and permit the accumulation of too much silver in the second bath, thereby defeating the purpose of the second bath. Longer times of fixation than 20 minutes, especially in the first bath, permit the retention of greater quantities of silver and hypo. With baths of low pH, if the total fixing time exceeds 20 minutes, reduction of the silver image may occur.²¹

(c) *When to Discard the Fixing Bath.*—Assuming that the pH is maintained and that there is no sludging or sulfurization, the fixing properties cease to be satisfactory when the concentration of silver in the bath exceeds a definite concentration because silver thiosulfate complexes are retained by the film. These critical concentrations of silver are indicated in Table X and may be determined with the Argentometer⁹ of Weyerts and Hickman. The "Kodak Testing Outfit for Fixing Baths"* has been adjusted to indicate the maximum practical degree of exhaustion of a film fixing bath which corresponds to a concentration of approximately 6.0 grams of silver per liter.

The Kodak Testing Outfit is particularly useful when two fixing baths are used. When a positive silver test is obtained with the first bath, it should be discarded. The second bath is then transferred to the first tank or tray to be used as the first fixing bath and a fresh solution used in the second tank.

In cases of ordinary processing when archival storage is not being considered, the preferred fixing procedure is to use two fixing baths, but if only a single bath is used, it should be discarded when the silver concentration increases to 6.0 grams per liter to avoid possible changes in the film which might occur in a very short time of keeping with quantities of silver greater than this.

In practice, the pH of a single bath usually increases to a degree depending upon the developer carry-over, but, if the pH exceeds 4.9, no silver is retained by the film. However, the clearing time

* To determine the exhaustion life of the first bath, add 10 drops of the fixing bath to 5 drops of the test solution B (from the Kodak Testing Outfit). An immediate heavy yellow precipitate indicates that the bath is exhausted.

is usually at the practical limit when the silver content is 6.0 grams per liter and the bath should then be discarded.

In the case of high-temperature processing using a chrome alum hardening bath and a non-hardening fixing bath, the fixing bath should be discarded when half exhausted.*

(3) *The Washing Procedure.*—The absolute time required to wash a given film emulsion is largely dependent upon the washing equipment and conditions used. The more effective the washing technique, the shorter the time of washing required to remove completely the hypo and silver.

Maximum and efficient removal of hypo and silver can be insured by observance of the following precautions:

(a) *Maintenance of an Adequate Rate of Renewal of Water at the Film Surface.*—In most cases neither the cascade nor the individual tank systems using large tanks produces sufficient agitation or renewal of fresh water at the film surface to insure the maximum rate of washing unless a large number of stages are used.

More rapid renewal at the film surface can be insured either by mechanical or air agitation or by spraying the water onto the film surface by a suitable arrangement of jets. It is preferable that the film be entirely submerged but, if this is not practicable, it is very important to insure a uniform flow of water at the film surface by staggering the nozzles and to take precautions that sprockets, shafts, chains, idlers, and other mechanical parts are adequately sprayed.

In order to insure maximum efficiency in washing, the volume of the wash tank for a given flow of water should be as small as possible so that the turn-over of the water is a maximum. With average conditions of washing when using a potassium alum fixing bath (pH less than 4.9), approximately one hour is required to wash out completely the hypo from the thicker high-speed negative emulsions such as Super-XX Negative Film, Type 1232. It is apparent, therefore, that satisfactory washing can not be attained with inefficient systems with a washing time of only 10 to 15 minutes.

(b) *Adjustment of the pH of Wash Water.*—The pH value of the wash water may be adjusted by the addition of ammonia at a rate sufficient to maintain the pH between values of 9.0 and 10.0. This may be accomplished by (1) automatic pH control apparatus now

* Add 5 drops of test solution B to 5 drops of water, then add 10 drops of fixing bath. A heavy yellow precipitate indicates that the bath is half exhausted.

commercially available, and (2) addition of ammonia water at a suitable rate by means of a constant-level device and a calibrated orifice.

The film should be rinsed before entering the tank in which the pH has been adjusted with ammonia; otherwise, when using a potassium alum bath a sludge of alumina would be produced. The water in the remaining tanks then washes the film free of hypo and ammonia. Ammonia in all the tanks has no advantage over its presence in one or two tanks. It is obvious that the use of several narrow tanks is to be preferred to only a few larger tanks. The use of squeegees will, of course, greatly minimize the quantity of hypo carried into the rinse and wash waters.

(c) *Control of Temperature of Wash Water.*—The temperature of the wash water should not be too low, the most useful and practical range being 60° to 70° F.

(4) *Fixing and Washing Paper Prints.*—It is obvious that certain steps must be taken to improve the commercial washing of photographic prints in order to produce prints which do not contain more hypo than the quantities previously indicated. In order to improve the washing, the following relatively simple operations should be adopted: (1) Raise the temperature of the wash water, (2) use adequate mechanical agitation, (3) prolong the washing time, and (4) employ the hypo eliminator² if lower quantities of hypo are desired.

The removal of hypo and silver from film by washing was greatly improved by (a) adjusting the pH of the fixing bath to a value in the range 5.0 to 5.5, (b) bathing in 0.03 per cent ammonia solution, (c) using a chrome alum fixing bath or the *F-6* potassium alum fixing bath, and (d) using a two-fixing-bath combination in which the second bath was non-hardening or at a pH value higher than 4.9.

However, with paper prints the above procedures assisted the removal of hypo by washing only to a small degree and only during the first few minutes of washing. Of these treatments the combination of two fixing baths was the only one which assisted in the removal of silver.

Recommended potassium alum fixing baths for use with prints are Kodak *F-1*, *F-5*, and *F-6*. Prints should be fixed for a minimum time of 5 minutes to insure thorough fixation in exhausted baths. Longer times of fixation up to 15 to 20 minutes may be used without affecting the silver image, but under these conditions greater quan-

tities of hypo and silver are retained. When using more than one fixing bath it is desirable to fix about 5 minutes in the first bath and from 3 to 5 minutes in subsequent baths. It is never desirable to

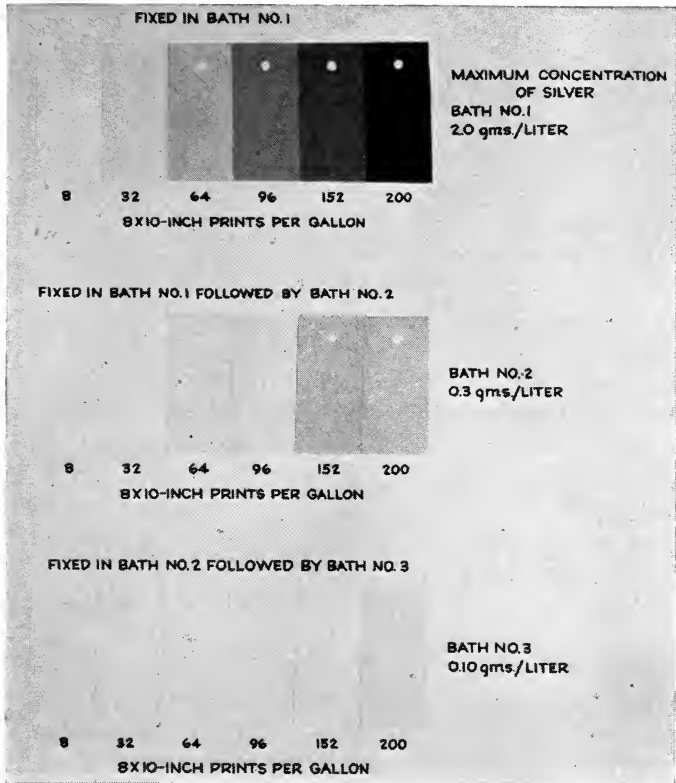


FIG. 14. Illustrating the relative quantity of residual silver in prints when fixed in multiple baths. After fixing and washing, the prints were stored at 110°F when the silver thiosulfates decomposed to yellow silver sulfide. The quantity of silver sulfide stain is therefore an indication of the probable appearance of the highlights of the prints on prolonged storage. Note that the exhaustion life of a single fixing bath is not greater than twenty-five 8 × 10-inch prints per gallon, but with three fixing baths the life is at least one hundred prints per gallon.

allow prints to soak for excessive times (30 minutes or upward) in the fixing bath because this tends to retard easy removal of hypo by washing and to reduce the image.

The intended use of the prints largely governs the method of

fixing to be employed. In order to obtain the most permanent prints possible, for archival purposes, it is imperative that at least two and preferably three fixing baths be used, preferably with a rinse between baths. The baths should be used until the first bath is exhausted as judged by the "Kodak Testing Outfit for Acid Stop Baths and Fixing Baths."* Then the second and third baths are used as the first and second baths, and the cycle is repeated.

Fig. 14 illustrates the relative silver sulfide stain produced by decomposition of the retained silver thiosulfates in prints fixed in the three baths during the processing of sufficient 8×10 -inch prints to give a positive silver test in the first bath with the Kodak Test Kit. It is seen that a second fixing bath will permit the fixation of about thirty 8×10 -inch prints per gallon which contain no silver, while the use of a third bath will permit the fixation of about one hundred 8×10 -inch prints per gallon. The baths were exhausted to two hundred 8×10 -inch prints per gallon with samples taken out for test as indicated. The silver content of the baths after this number of prints was processed is indicated. These values were determined with the Argentometer described by Weyerts and Hickman.⁹

Following thorough fixation in at least two successive fixing baths, the prints should be washed, treated in the hydrogen peroxide-ammonia hypo eliminator,² washed, and further protected against atmospheric conditions as recommended in the paper "The Elimination of Hypo from Photographic Images."² The use of at least two and preferably three fixing baths previous to the use of the eliminator is imperative since the eliminator does not remove silver thiosulfates. In the absence of thorough fixation, early decomposition of the residual silver complexes to silver sulfide may occur causing staining of the highlights of the print.

When a single fixing bath is used until exhausted as indicated by the Kodak Testing Outfit, it contains about 1.2 to 1.5 grams of silver per liter. Prints fixed in this solution will keep for a short time only, especially under adverse storage conditions. The maximum concentration of silver in a fixing bath considered to be safe for commercial purposes is approximately 0.30 gram per liter which

* To determine the exhaustion life of the first bath, add 5 drops of test solution *B* to 5 drops of water and then add 10 drops of the fixing bath. The bath is exhausted when a permanent heavy yellow precipitate forms. This test is designed to measure the much lower critical concentration of silver in paper fixing baths.

means that only about thirty 8×10 -inch prints per gallon should be fixed in a single bath.

It is therefore considered necessary, as well as more economical and practical, to use two fixing baths in commercial processing. By this means the first bath can be exhausted, before being discarded, with one hundred fifty 8×10 -inch prints per gallon of fixing bath. This exhausted bath may then be replaced by a fresh bath and when this bath is exhausted with one hundred fifty 8×10 's per gallon, the second bath may be used as the first bath. An alternative is to exhaust the first bath which is then replaced by the second bath and a fresh second bath employed. The exhausted bath should contain about 1.2 to 1.5 grams per liter of silver and give a positive test with the Kodak Testing Outfit.

A further saving in time, because of less handling, will result from the use of three fixing baths, in which case four fresh first baths may be exhausted before it is necessary to move the second and third baths into the first and second positions, after which three more fresh first baths may be used, and so on. This method is not satisfactory for the complete removal of residual silver, but only when 0.30 gram of silver per liter in the fixing bath can be tolerated.

The use of multiple fixing baths may be simplified by the adoption of a continuous countercurrent flow of the fixing bath through a series of at least two tanks. This arrangement would eliminate the necessity of (a) moving the tanks from one position to another, (b) transferring the baths from one tank to another, or (c) replenishing the bath in a single tank by flowing in fresh solution at a constant rate. A countercurrent flow system would also reduce the loss of silver usually incurred by the carry-over of partially exhausted fixing bath into the wash water since the silver content of the last fixing bath would be at a minimum.

It has been suggested that a fewer number of fixing baths containing much greater quantities of hypo (*e. g.*, 60 per cent) could be used. Tests made in this connection did not show any practical advantages in the use of such baths.

To Summarize.—The above recommendations insure as well as is known the absence of silver thiosulfate and free hypo in the finished negative or print and, although in most cases, if the hypo and silver contents are reduced to the permissible values suggested in Tables IX and X, satisfactory permanency can be expected, it is desirable to follow the procedure for complete elimination in

order to take care of possible inefficiencies in either the fixation or washing procedures and of possible abnormal conditions of storage.

Although emphasis has been placed on the production of permanent films and prints with respect to the silver image, it is of equal interest and importance that the photographic base shall have equal permanency.

Experience has shown that many high-grade book papers have retained their original characteristics for several hundred years, and aging tests made by the Bureau of Standards ^{22, 23} have indicated that paper stock of the type used in photographic paper is as permanent as the high-grade book papers tested. It is, therefore, reasonable to assume that the photographic paper base will keep, at least, for two or three hundred years.

In the case of films free of residual hypo and silver and stored at 50°F or lower those with nitrate film base will probably remain unchanged for at least 100 years. It is recommended, however, that films for record purposes be made on safety (acetate) base since accelerated aging tests made by the Bureau of Standards¹ have indicated a greater permanency for acetate as compared with nitrate film base.

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The authors are indebted to Mr. C. E. Ives for helpful suggestions and to Mr. C. J. Kunz for assistance in the experimental work.

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rate of washing are (1) the temperature of the wash water, and (2) the composition of the fixing bath. The rate of removal increased with increased temperature and when non-hardening fixing baths were used instead of hardening fixing baths. Chrome alum hardening fixing baths increased the rate of washing as compared with potassium alum baths. The necessity for the elimination of hypo in prints to a low limit is shown and the development of an efficient peroxide-ammonia eliminator for prints is described.

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EFFECT OF HIGH-INTENSITY ARCS UPON 35-MM FILM PROJECTION*

E. K. CARVER, R. H. TALBOT, AND H. A. LOOMIS**

Summary.—*In the study of the effects of high-temperature arcs on 35-mm motion picture projection, it was noticed that the sharpness of the image on the screen was materially affected by changes in the heat intensity. This indicated that film does not always lie in a flat plane in a projector gate but takes different positions at different temperatures. In order to study this phenomenon more carefully, a portion of the projector gate was cut away permitting high-speed Ciné Kodak pictures (about 1500 frames/second) to be taken of the film as it passed by the aperture of a projector. The pictures show that most films enter the gate in a state of slight positive curl (curl toward the emulsion) and then change to a state of negative curl during the instant they remain exposed to the heat of the arc. This change in curl is due to the expansion of the emulsion layer by the heat. This effect is especially pronounced with the new high-intensity arcs.*

The effect on the quality of the screen image of this change in curl of the film in the gate was studied by means of high-speed Ciné Kodak analysis of the screen image. The pictures show that at high heat intensities and with the projector focused to give the sharpest image on the screen, the images are in sharp focus for only a portion of their duration on the screen. Each screen image comes into view out of focus and gradually becomes sharper until just before the pull-down when it reaches its maximum sharpness. Such pictures are of good screen quality if the projector is focused carefully.

Under certain conditions, when the film is in a very moist state and when lamps of the highest heat intensity are used, the screen images may not all be sharp. Occasionally a few frames may be entirely out of focus. The high-speed analysis of the action of the film in the gate shows that these out-of-focus frames behave in an abnormal manner. In these frames the normal change in curl from positive to negative in the gate is interrupted by a reversal back to positive curl. Thus at the end of the pull-down cycle these frames lie in a plane slightly toward the lens of the projector, whereas all of the normal frames lie in a plane slightly toward the lamp from the plane of the gate. The distance between these two planes is greater than the depth of focus of the lens and thus these abnormal frames appear out of focus. It is believed that this sudden reversal to positive curl is due to a contraction of the gelatin due to loss of moisture.

We recommend that the heat intensity at the aperture, as measured by a thermocouple which we have described, should not exceed 1250° F and that films should be dried thoroughly.

* Presented at the 1942 Fall Meeting at New York, N. Y.

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Recent improvements in arc lamps and carbons which have made possible brighter pictures on the screen have brought forward again the problem of the effect of extreme heat on motion picture film.

Whereas in the past a thermocouple held in the gate of a projector seldom reached a temperature of 1000°F, some of the arcs and lamps now in use may heat the thermocouple to as high as 1700°F. These excessively high temperatures are not without effect upon the physical state of the film subjected to them and consequently on the resulting picture quality.*

The purpose of this paper is to illustrate the physical changes that take place in the film during the brief time it remains stationary in the gate of the projector and is subjected to these high temperatures, as well as the effect that these phenomena have upon the appearance of the screen images.

Shift of Focus with Changes in Arc Intensity.—Changes in the heat intensity at the aperture were measured by inserting a thermocouple at the center of the aperture in the exact plane normally occupied by the film. An iron-constantan thermocouple terminating in a stainless steel disk 6 mm in diameter was employed. The temperature which this thermocouple will attain is arbitrarily called "heat intensity." This manner of estimating heat intensities is admittedly empirical, and is influenced by the size and color of the disk, radiation therefrom, *etc.*, but furnishes quite reproducible results.

It was noticed immediately that the sharpness of the picture upon the screen was influenced materially by the heat intensity. A picture whose image was in sharp focus with a heat intensity of 1000°F could be thrown decidedly out of focus if the heat intensity were raised or lowered a few hundred degrees. This indicated that film does not always lie in the same plane in the gate but takes different positions at different temperatures. In order to demonstrate this more clearly and at the same time obtain a measure of these displacements, it was necessary to calibrate the projector lens system

* The original title of this paper was, "Effect of High Gate Temperatures upon 35-Mm. Film Projection." The use of the expression, "gate temperatures," was criticized severely (and correctly) because of the fact that the gate itself does not have a high temperature. The gate is merely a pathway through which the intense radiant heat travels. The thing of importance is the intensity of this heat flux and not the temperature of the air within the gate, which, of course, is approximately room temperature. The new title, therefore, describes more accurately the effects to be discussed.

so that axial displacement of the center of the film in the aperture could be followed by noting the distance the lens must be moved from its normal position to keep the image in sharp focus upon the screen.

Study of Film Movement in Aperture by Focusing Method.—The lens system was calibrated by attaching an indicator to the system as shown in Fig. 1. The lower part of the indicator hand is attached

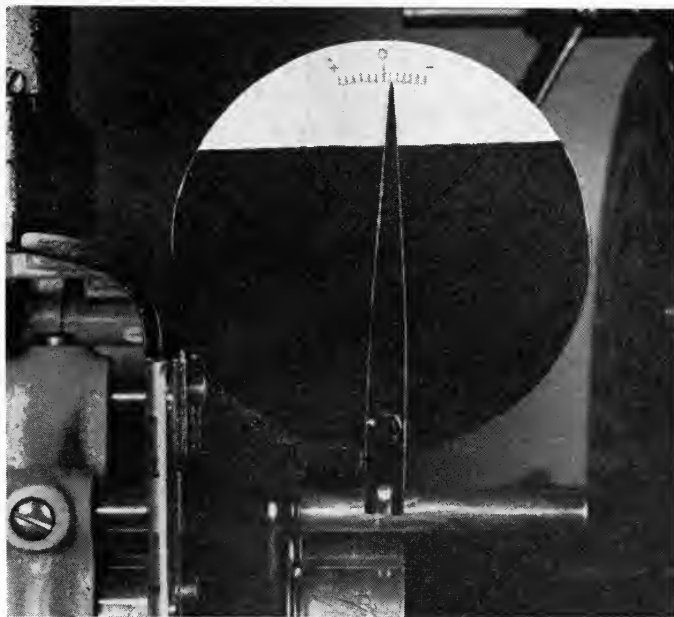


FIG. 1. Focus indicator on E-7 projector.

directly to the lens barrel, then to a fixed fulcrum which magnifies the displacement at the tip of the pointer so that lens movements of 0.01 inch are read plainly and movements of the order of 0.0025 inch can be estimated.

The focus indicator was calibrated in the following manner: A strip of film was held in a perfectly flat position in the gate by means of a piece of steel 35 mm in width. A small hole drilled in the center of this metal strip allowed a portion of the test image to be projected upon the screen. Since the film was not in motion a faint source of light was used at a considerable distance from the film in order to

eliminate any heat effect. Thus the lens setting for best visual focus for perfectly flat film in the gate was established. This we shall call "zero focus." In a like manner, the lens setting for film that has been displaced a known amount was obtained by mounting the film on metal shims of known thickness and placing the shims against the

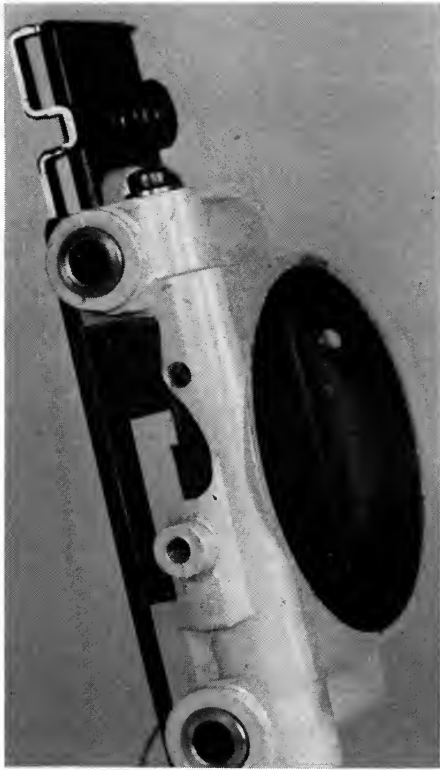


FIG. 2. *E-7* gate cut away for aperture pictures.

film trap. Thus if a shim 0.01 inch in thickness were used, the film would be moved axially toward the lens 0.01 inch. The best visual focus was again obtained by projection of the image and the focus indicator calibrated. As is well known, film that curls so that the emulsion side is concave is referred to as having "positive curl," and film that curls in the opposite direction is referred to as having "negative curl." Since the film in the gate has its emulsion side toward the arc,

and has its edges pressed against the gate, it will be seen that if film has positive curl, the image plane at the center of the film will be shifted toward the lens of the projector. The shift of the lens in order to correct for this displacement will be referred to as a *positive* focus. In like manner, if the film in the gate of the projector has a



FIG. 3. E-7 gate with reference bar attached.

negative curl, the image plane at the center of the film will be displaced in the opposite direction or toward the lamp. The shift of the lens to correct for this displacement will be referred to as a *negative* focus. Thus it may be seen that the effective position of the film in the gate, so far as the screen image is concerned, may be arrived at during projection simply by setting the lens at the best

visible focus and reading the displacement of the lens in hundredths of an inch on the dial.

It was discovered immediately that almost without exception new films projected at the customary heat intensity of about 850°F or higher assumed a negative curl in the aperture. This was viewed at first as a rather disconcerting discovery inasmuch as such films are

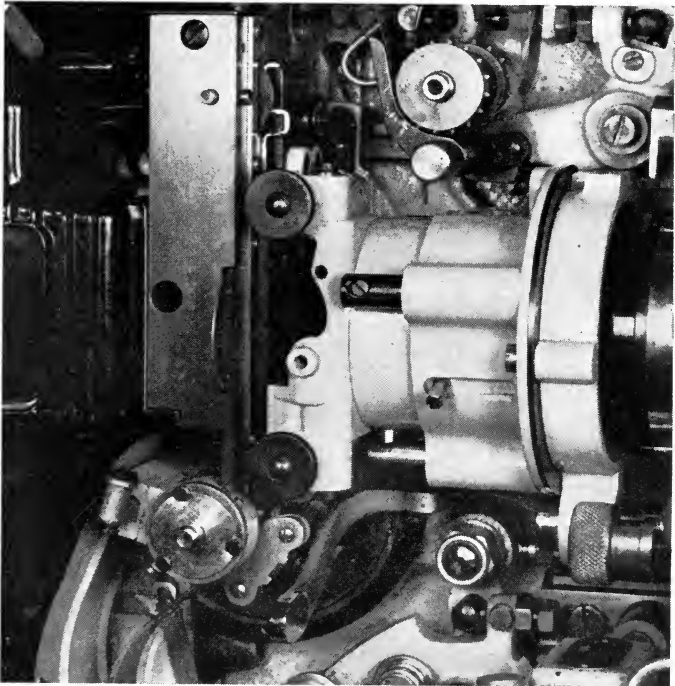


FIG. 4. Cut-away E-7 gate on projector.

almost always in a state of slight positive curl. In fact, film entering and leaving the gate was observed to have slight positive curl, and yet the focus indicator showed plainly that the film in the aperture, while the image was being projected upon the screen, was negative in curl to the extent of, in many cases, at least 0.01 inch. On the other hand, it is quite logical to assume that temperatures of this magnitude, even though operating but for an instant, could effect this change in the physical state of the film. One has, in effect, a situation analogous to a bimetallic strip such as is used in many

thermostats. This consists of two bonded metal strips, one having a greater coefficient of expansion than the other. When heated, the strip is forced to assume a curvature convex to the more rapidly expanding element. In our case, the emulsion layer and the support form the two members of the strip. The expansion takes place almost wholly in the emulsion layer since the support absorbs practi-

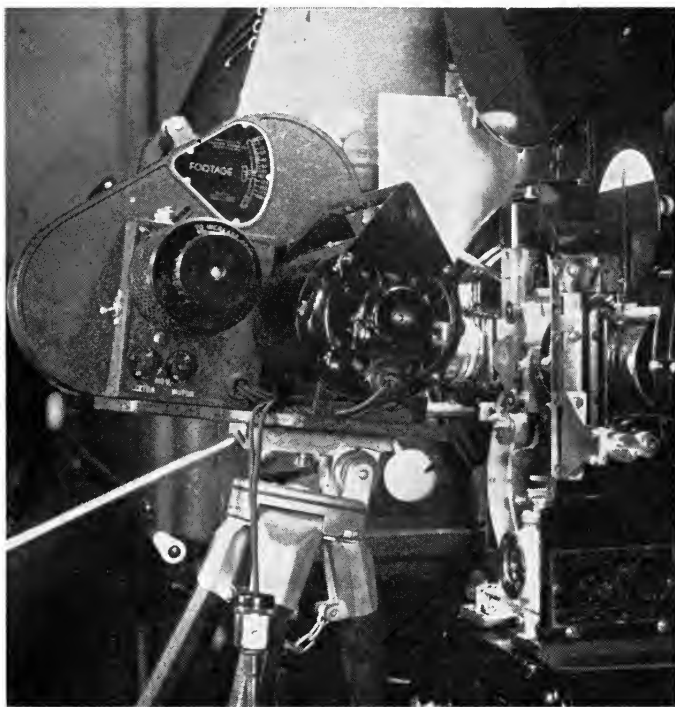


FIG. 5. High-speed Ciné Kodak focused on aperture.

cally none of the heat. Expansion of the emulsion layer would force the strip of film to be convex to the emulsion or negative in curl.

Study of Film Travel in Aperture by High-Speed Camera Analysis "Negative Drift."—In order to determine at what point in the pull-down cycle the reversal of curl took place, high-speed motion pictures were taken of the film as it passed through the aperture. In most of this work, a Simplex E-7 projector with a McAuley Hy-Candescent Lamp and New Super H.I. National carbons was used. However,

certain phases of the work were repeated with other projectors and other lamps and the same results were obtained.

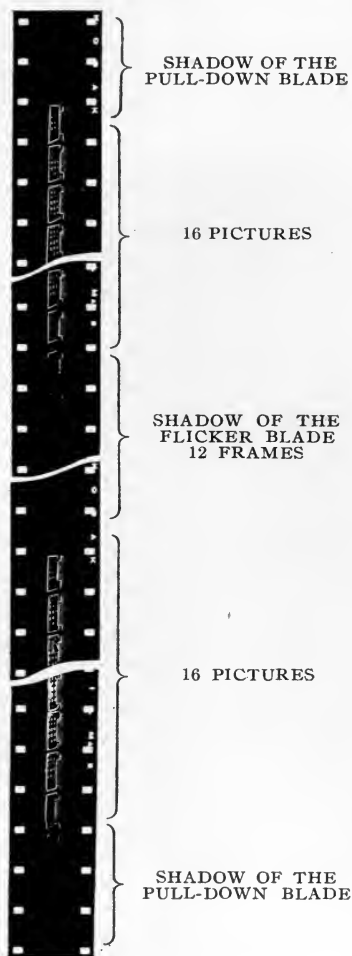


FIG. 6. High-speed pictures of 35-mm film in the aperture. The pictures represent the interval from the end of one pull-down to the start of the next pull-down.

It was necessary to cut away a portion of the *E-7* gate, as shown in Fig. 2, in order to obtain the pictures of the film as it passed by the aperture. A reference bar was attached to the gate so that slight movements of the film in relation to this bar could be observed. (See Fig. 3.)

Fig. 4 shows this special gate in place on the projector and Fig. 5 shows the high-speed Ciné Kodak in position to take the pictures. The pictures were taken at an angle of about 15 degrees from the plane of the film.

By this means pictures have been taken of film in the aperture of projectors at a rate of about 1500 frames per second. In other words, with film traveling through the 35-mm projector at the normal rate of 24 frames per second and with the film remaining stationary in the aperture for $\frac{1}{32}$ second, about sixty 16-mm exposures were made between successive pull-downs. As is known, there are two blades on the shutter of a standard 35-mm projector. One blade is to mask the movement of the film as it comes into place in the aperture, and the purpose of the other blade is to interrupt the light once during projection so as to keep the periods of dark and

light on the screen of more equal duration and thus minimize flicker. Therefore, the 16-mm high-speed pictures have a dark portion of

about 12 frames between consecutive pull-downs of the 35-mm film, representing the blocking-out of the light by the flicker blade. A typical sequence of pictures obtained from the end of one pull-down to the beginning of the next is shown in Fig. 6.

When the 16-mm pictures were projected the movement of the 35-mm film in the aperture of the projector could be clearly seen.

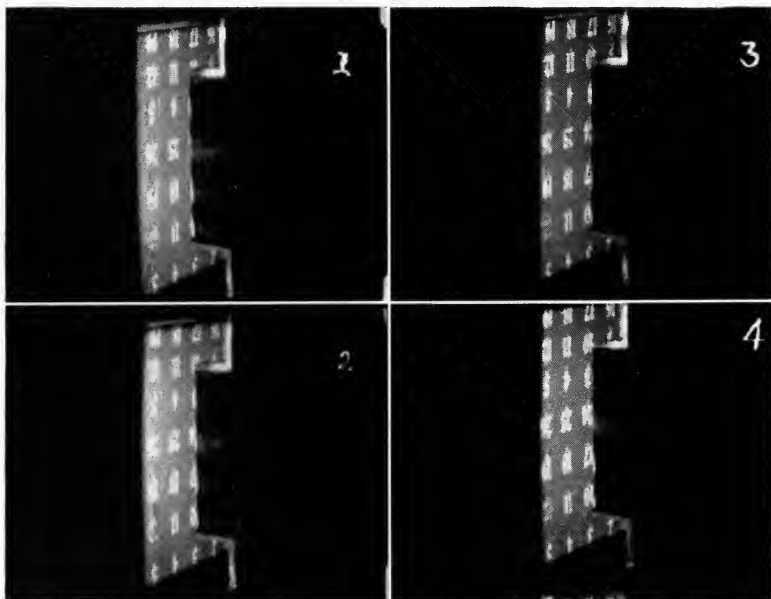


FIG. 7. Enlargement of four frames from film shown in Fig. 6.

- (1) Immediately after the pull-down.
- (2) Immediately before the flicker blade.
- (3) Just after the flicker blade.
- (4) Just prior to the next pull-down.

The pictures show that the film comes into the aperture in its normal state, *i. e.*, flat or slightly positive in curl; then as the heat strikes the film the emulsion layer expands, forcing the film into a state of negative curl. The expansion of the film starts immediately after the pull-down and reaches its maximum just before the next pull-down. The passing of the flicker blade halts this expansion effect momentarily.

Fig. 7 is an illustration of four 16-mm frames taken of one complete 35-mm pull-down cycle. No. 1 frame was taken immediately

after the pull-down; No. 2 frame immediately before the flicker blade; No. 3 frame just after the flicker blade; and No. 4 frame just prior to the next pull-down. In the pictures the reference bar can be seen protruding into the aperture. The movement of the film can be noticed by observing the position of the numbers in relation to the reference bar at different portions of the pull-down cycle. In the No. 1 frame, the third column of figures from the left is masked completely by the reference bar; in No. 2 frame, this column of



FIG. 8. Scene used for high-speed screen pictures. The encircled portion is the target.

figures has moved out almost into view. In No. 3 frame, the film appears to be in about the same position as in No. 2 frame. This is due to the hesitation or even slight retraction of this heat-expansion effect as the flicker blade passes between the light and the film. In No. 4 frame, the third column of numbers is in full view.

The lateral displacement or change of curl produced by the absorption of heat in the emulsion layer is a normal phenomenon, and takes place with all types of film, *i. e.*, it is the same for fine-grain positive as for the older type of positive, and it takes place to an equal extent in all manufacturers' films that have been tested. It is

dependent upon the heat intensity and the density of the image; the higher the heat intensity, the greater is the displacement. Likewise, the greater the density, the greater is the displacement, since more heat is absorbed. Strange as it may seem, the displacement is independent of the natural curl of the film—a film having a high positive curl will be displaced to the same extent as a film with little or no curl.

Effect of "Negative Drift" on the Appearance of the Screen Image.—It will be of interest now to examine what effect this "negative drift,"

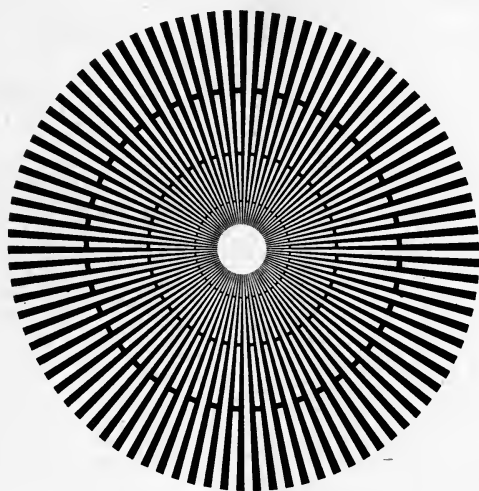


FIG. 9. Enlargement of target.

as it is frequently referred to, has upon the quality of the screen image. In order to demonstrate this, the high-speed camera with a telephoto lens was focused upon a portion of the screen image, as shown in Fig. 8. The portion of the screen image encircled in the above figure consists of a focusing chart, an enlargement of which appears in Fig. 9. The projector was focused to produce a sharp image upon the screen. As stated before, this required that the lens be focused upon a plane 0.01 inch toward the lamp from the aperture. The images appeared sharp to an observer a few feet from the screen. There was, of course, some lack of definition due to the extreme magnification. When the 16-mm high-speed pictures were projected, it was seen that for each pull-down cycle the 35-mm screen

image was out of focus when it first came into view. It then became sharper and sharper until, after the flicker blade and just prior to the next pull-down, the image was in sharp focus. A series of four frames taken from this 16-mm high-speed film is shown in Fig. 10.

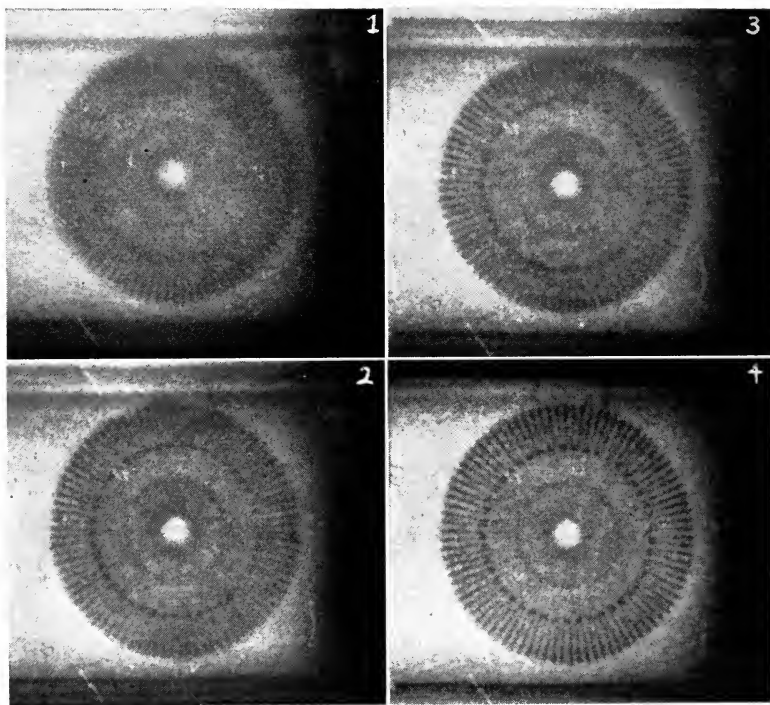


FIG. 10. Enlargement of four individual frames from high-speed screen pictures.

- (1) Immediately after the pull-down.
- (2) Immediately before the flicker blade.
- (3) Just after the flicker blade.
- (4) Just prior to the next pull-down.

As before, the four frames represent different portions of the pull-down cycle. No. 1 frame was taken immediately after the pull-down; No. 2 frame immediately before the flicker blade; No. 3 frame just after the flicker blade; and No. 4 frame just prior to the next pull-down.

The appearance of the screen image with different focus settings of the projector lens was tested using a set-up as shown in Fig. 11.

A cord was wound about the focusing knob of the projector lens and attached to an indicator on the screen in such a manner that the exact focal setting of the projector lens appears in the 16-mm pictures of the 35-mm screen image. In operation the projector is started and the image thrown on the screen with the projector lens focused $+0.02$ inch. The high-speed camera is started and as soon as it has attained maximum speed, the focus of the projector lens is gradually changed to a focus of -0.02 inch, the movement being recorded by the indicator on the screen.

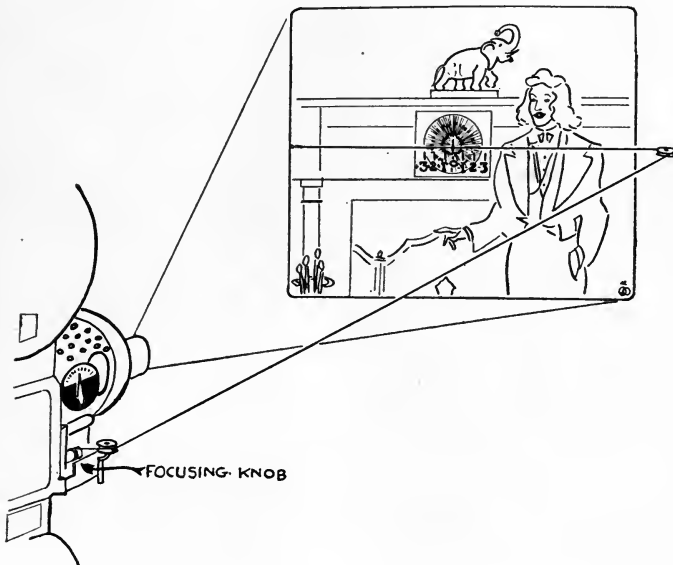


FIG. 11. Set-up for recording the setting of the 35-mm projector lens on the high-speed pictures of the screen image.

With the projector focused on the positive or lens side of the aperture, the image is in sharp focus only immediately after the pull-down, since at this point it is nearest to the plane on which the projector lens is focused. As the film in the aperture drifts away from this original position or toward the negative plane nearer the arc lamp, the film moves beyond the depth of focus of the lens and the image appears out of focus. A series of four frames taken from this portion of the film is shown in Fig. 12. In these pictures the indicator shows that the projector lens was focused at about $+0.008$

inch or on a plane 0.008 inch toward the lens from the aperture. As the focus of the projector lens is changed to the negative or lamp side of the aperture, the effect is the opposite. Here the image comes into view out of focus and changes steadily to sharp focus. This is shown in Fig. 13. In these pictures the indicator shows that the projector

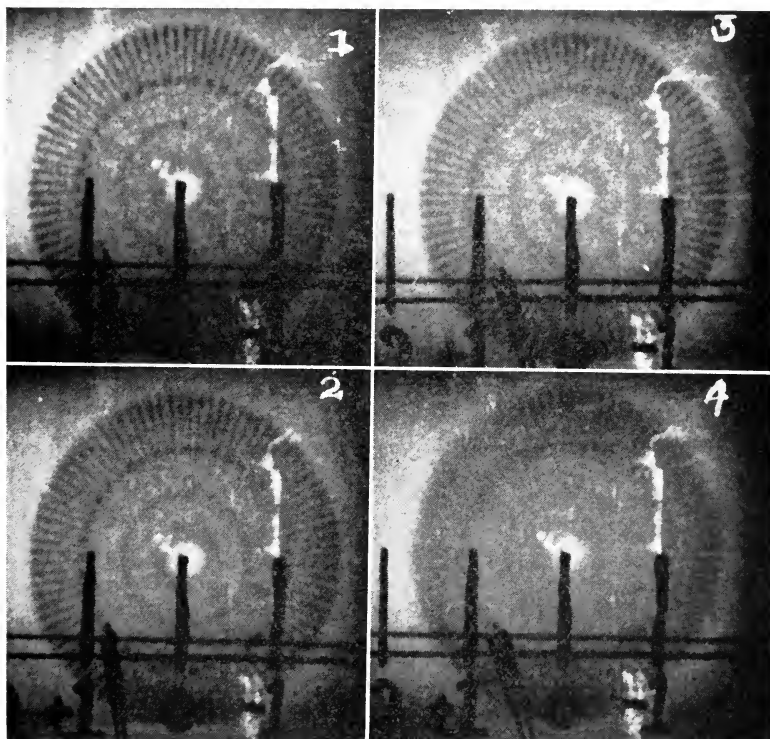


FIG. 12. Enlargement of four individual frames from high-speed screen pictures, with projector lens focused at $+0.008$ inch.

lens was focused at about -0.005 inch or on a plane 0.005 inch toward the lamp from the aperture.

The reason why the projected images appear sharpest when the projector is focused on the negative plane is not understood definitely. It is stated simply as an observation repeated many times with various films, projectors, and operators. It may be that the film in the aperture is in a state of rapid movement during the first one-half or three-quarters of the pull-down cycle due to this heat

expansion effect. It is only after this expansion has taken place that the film remains relatively stationary. Possibly the eye prefers to focus upon the image during that portion of the cycle in which the film is relatively free from motion even though this period represents but a fraction of the entire cycle.

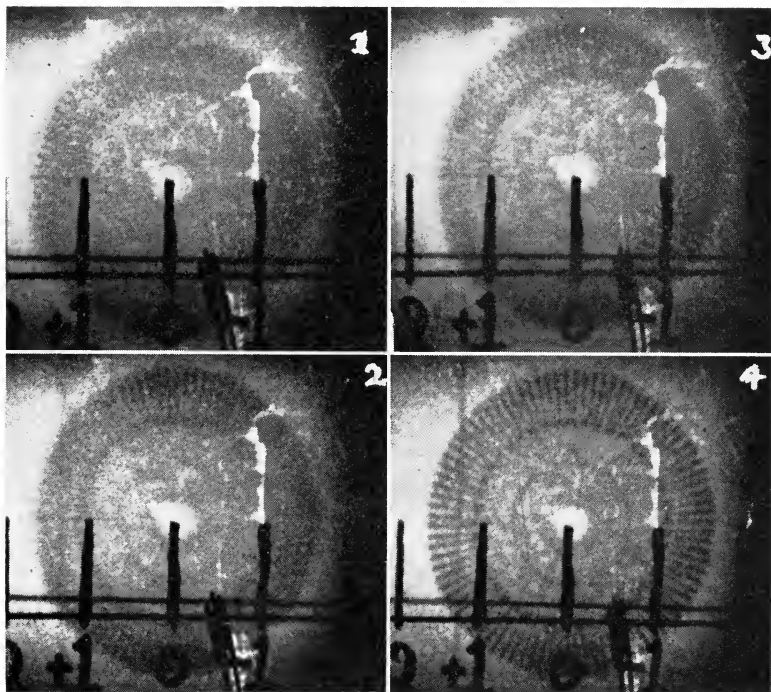


FIG. 13. Enlargement of four individual frames from high-speed screen pictures, with projector lens focused at -0.005 inch.

All the film which we have described has been perfectly normal. No in-and-out of focus was observed upon the screen, and excellent projection quality was obtained in spite of the negative drift observed with the high-speed movies. The effect has been obtained with film of all manufacturers and with many types of experimental film. The effect is apparent at all heat intensities above 850°F as measured by our thermocouple using the particular print with which we experimented most. In spite of the fact that sharp pictures were obtained even though this negative drift was occurring, nevertheless

it was certainly true that the focusing had to be far more carefully done with the high temperatures, when the negative drift was large, than with the low temperatures, when it was absent.

The "In-and-Out of Focus" Phenomenon.—Up to this point the work that has been presented might be regarded as largely of academic interest, its purpose being to contribute to our knowledge of the normal operation of films in 35-mm projectors operating at high heat intensities. However, much trouble of a serious nature has been encountered in the trade with a condition that has come to be known as the "in-and-out of focus" difficulty. In a number of theaters, particularly in the *de luxe* houses, it has been impossible at times to keep the image in sharp focus upon the screen. The effect is exactly what the designation "in-and-out of focus," implies; that is to say, the image is perfectly sharp the greater part of the time but occasionally goes out of focus momentarily. Usually the first few projections of prints subject to this difficulty are normal. After four or five projections or thereabouts, and for several succeeding projections, it may become difficult, if not impossible, to keep the picture in sharp focus.

It was some time after this difficulty was encountered before the mechanism by which it took place was discovered. Since it occurred most frequently with high-intensity arc projectors which often emboss the film, many believed that the focusing difficulties were associated with this embossing. However, it is a matter of record that the difficulty may occur in the initial projection of a print on which there is no embossing or distortion of any kind. Likewise this in-and-out of focus difficulty disappears with repeated projections during which time the embossing of the film increases gradually.

Again it was by high-speed analysis of film movements in the aperture that the true cause of the difficulty was discovered. We were able eventually to obtain high-speed pictures of film in the gate of a projector at the exact instant the picture was seen to go out of focus on the screen. The difficulty of obtaining such pictures may be realized by considering that even during bad in-and-out of focus trouble only relatively few frames of an entire roll exhibit the defect and it is impossible to tell beforehand when the trouble is about to occur. The time required to expose 100 feet of film in a high-speed camera is about 3 seconds, and once the camera is started the entire roll must be run off. Therefore, most of our shots show the action of perfectly normal film. High-speed aperture pictures of film sub-

ject to this difficulty show that the great majority of frames behave in a normal manner, *i. e.*, enter the gate in a state of slightly positive curl and expand to a state of negative curl. The projector is, therefore, focused on this negative plane. Suddenly, however, a few frames come into position in the normal manner, start to expand, and then, before reaching the plane of critical focus, jump back again into a state of positive curl. These frames, because of their position at the end of the cycle, are outside the plane of sharp focus of the projector lens, and their images are therefore more or less completely out of focus on the screen.

In order to determine what factors caused certain films to behave in this manner, the variables of processing and projection were studied that were thought to have any bearing on the subject. Of the various processing variables, only one was found to have any influence on the in-and-out of focus effect—the amount of moisture left in the film after drying. If the film is not dried sufficiently the in-and-out of focus effect is increased greatly. This and other observations have led us to believe that the sudden shift in curl of the frames that appear out of focus is due to a drying-out of the emulsion under the influence of the high heat intensity in the aperture. It is believed that the reason why insufficiently dried films exhibit the in-and-out of focus defect is that (1) there is more moisture in the emulsion, which therefore contracts more on losing this moisture, and (2) the moisture tends to make the film base softer at high temperature, thereby offering less resistance to the pull of the emulsion than if the film base were drier. These effects, due to insufficient drying, formerly caused some real difficulty with the use of certain fine-grain films. These emulsions reached the point of sensible dryness in the drying cabinet in about one-third the time required for the older type of film. As a consequence some of the laboratories used milder drying conditions for the fine-grain film in order to cause it to dry in the same position in the cabinet as the type previously used. Thus, even though the emulsion appeared dry there was certainly more moisture both in the emulsion layer, and particularly in the support, than in the case of films dried under the older conditions. Upon correcting these drying conditions much of the in-and-out of focus difficulty disappeared.

The various factors in the projection of film that might influence the in-and-out of focus effect on the screen were also studied. These were found to be the characteristics of the lens, the angle of pro-

jection, and the heat intensity. In general, the more critical the lens, the more carefully it must be focused. Thus an $f/2.0$ coated lens gives a picture of superb quality if the lens is focused with extreme care, but the depth of focus is so small that a slight misadjustment of the lens causes small movements of the film in the aperture to be noticeable on the screen. Likewise a steep angle of projection produces the same effect as decreasing the depth of focus of the lens.

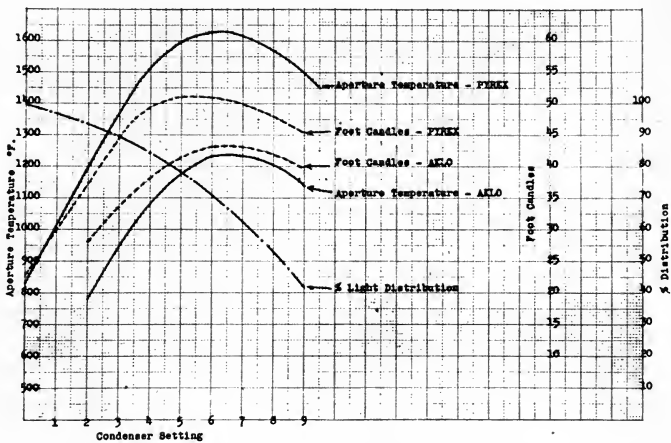


FIG. 14. Effect of Aklo heat-absorbing filter on the heat intensity at the aperture of a 35-mm projector and on the light intensity at the screen. The "aperture temperatures" are the temperatures reached by the thermocouples when placed at the center of the aperture. The per cent light distribution indicates the ratio of the illumination at a point 5 per cent of the screen width from the edge of the screen to the illumination at the center of the screen.

The third factor, the heat intensity, was found to be of great importance. It has been observed many times that films exhibiting the in-and-out of focus effect upon the screen at heat intensities of 1700°F would project satisfactorily if the heat intensities were reduced to 1250°F . High heat intensities cause the expansion and contraction forces operating on the emulsion to be more violent in nature and, at the same time, soften the film base so that it is less able to withstand them.

One obvious method of reducing the heat intensities of these high-intensity lamps is to insert a heat-absorbing filter between the lamp and the projector. Fig. 14 shows the reduction of heat and light,

effected by this procedure. The abscissa values correspond to the various positions of the condenser lens. The low numbers refer to a position close to the arc, thus giving a large spot and consequently low heat intensity and light values. At the point of maximum heat and light or at a condenser setting of about No. 6, the insertion of the heat-absorbing filter has effected a 23.5 per cent reduction in heat intensity with a reduction of but 14 per cent in light at the center of the screen.

As the result of this work, we feel justified in making two recommendations to the trade: one concerning heat intensities and the other dealing with the drying of film. It is recommended that the heat intensity at the aperture of a projector be kept down to approximately 1250°F by the use of heat-absorbing glass* or other means. It is recommended also that processing laboratories dry their films more thoroughly, taking into consideration the fact that the film base must be dried as well as the emulsion. It should be pointed out, however, that under certain conditions overdrying of films may result in "spoky" rolls, a defect that is discussed in the paper, "Film Distortions and Their Effect upon Projection Quality."¹

Acknowledgment.—In conclusion, we wish to give full acknowledgment to Mr. Eldon E. Moyer for the time and skill expended in taking these high-speed motion pictures, and to Dr. Alfred C. Robertson and Dr. Geoffrey Broughton for many suggestions contributed to the work.

REFERENCE

- ¹ CARVER, E. K., TALBOT, R. H., AND LOOMIS, H. A.: "Film Distortions and Their Effect upon Projection Quality," *J. Soc. Mot. Pict. Eng.*, **XLI** (July, 1943), p. 88.

* A piece of Corning Extra Light Shade Aklo heat-absorbing glass 4¹/₄ inches in diameter and 1.2 mm thick was used in place of the Pyrex glass normally found between the lamp house and the mechanism of the E-7 projector. To minimize breakage, the glass was cut into five strips about ⁷/₈ inch wide.

FILM DISTORTIONS AND THEIR EFFECT UPON PROJECTION QUALITY*

E. K. CARVER, R. H. TALBOT, AND H. A. LOOMIS**

Summary—The five most generally recognized types of film distortion are discussed. These consist of curl, spokiness, embossing, flute or long edges, and buckle or short edges.

Curl has come to be an accepted fact and is ordinarily without importance in projection except when it becomes excessive.

Spokiness, sometimes called square rolls or hexagonal rolls, is a phenomenon observed when film with a high degree of curl is wound with insufficient tension to keep the roll perfectly round. Poor screen quality in the case of 16-mm films has sometimes been associated with this defect.

Embossing is due to differential shrinkage or hardening of the emulsion caused by local absorption of heat in the dense portion of the picture. Careful tests have failed to show any effect upon the screen such as in-and-out of focus due to image embossing. Measurements of the magnitudes of the distortions show that these are ordinarily much less than the depth of focus of the lens.

Flute, or long edges, is more often seen with safety film than with nitrate film. It is generally caused by a stretching of the edges by recessed rolls, by shrinking the center of the film with high-temperature arcs on projection, or by exposing the roll to excessively high humidities, which causes swelling at the edges. Laboratory tests as well as field experience indicate that fluted edges very rarely cause distortion of the images on the screen.

Buckle, or short edges, is believed to be the most serious type of film distortion. It is caused by greater loss of moisture or solvent from the edges of the film than from the center. This leaves a fullness of the center resulting in an "oil-can" effect when film passes through the projector, thus producing pictures that go in-and-out of focus on the screen.

Buckle trouble may result from storing rolls of film in packages that are easily permeable to moisture vapor but it may be avoided by the use of impermeable packaging materials.

There are several types of film distortion commonly observed in processed film in the trade. Of these the most important are curl, spokiness, embossing, flute or long edges, and buckle or short edges. They are all caused by expansion or contraction, stretching or shrinkage, of certain portions of the film.

* Presented at the 1942 Fall Meeting at New York, N. Y.

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

Curl.—Curl has come to be an accepted fact and is ordinarily without importance in projection except when it becomes excessive. It is ordinarily caused by shrinkage of the gelatin emulsion at low humidities, when it is known as front curl, face curl, or positive curl. When the emulsion has swelled at high humidities or the base has shrunk, so as to make the emulsion side convex, the curl is called back curl or negative curl.

Spokiness.—Spokiness is a phenomenon observed when film with a high degree of curl is wound with insufficient tension to keep the roll perfectly round. The explanation appears to be as follows: A plane sheet of material can easily be bent or curled in one direc-

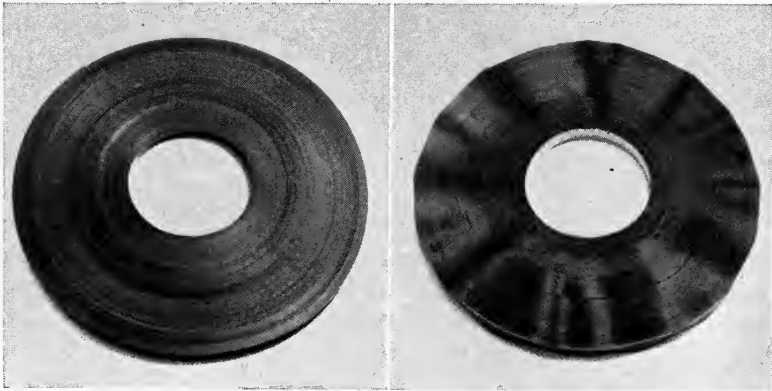


FIG. 1. (Left) smooth roll; (right) spoky roll.

tion or another, but strongly resists bending in two directions at the same time. Thus when a strip of curly film is wound into a roll, there is a tendency for each layer to resist bending for part of a turn and then to bend sharply. As successive layers are wound on, each break reinforces the last until a definite hump has been formed. There will be a succession of these humps around the roll giving a characteristic appearance when the roll is viewed from the side. The successive humps appear as radial lines, somewhat like the spokes of a wheel. Such rolls are referred to as being "spoky."

Sometimes, due to the fact that the rolls appear polygonal rather than perfectly round, they are referred to as square, octagonal, or hexagonal rolls, regardless of the exact number of sides of the polygon. A spoky roll is shown beside a smooth roll in Fig. 1.

Spokiness occurs both with 35-mm and with 16-mm film but does not appear to cause projection difficulties with 35-mm film. With 16-mm film, possibly because there is greater tendency for the spokes to "set" in the film, or possibly because of the lower pressure on the gate shoes in the projectors, in-and-out of focus effects are sometimes produced by the film distortion resulting from spokiness. Spokiness is generally the result of overdrying in processing, resulting in film of high positive curl, and of loose winding, which allows film of high curl to spoke more readily. We must choose, therefore, a middle course between overdrying and underdrying. The former may result in focusing difficulties as a result of spokiness; the latter may give thermal "in-and-out of focus" effects such as described in the paper, "Effect of High-Intensity Arcs upon 35-mm Film Projection."¹

Two distinct kinds of spokiness may be observed. If curly film is wound with the concave side out, the spokes visible on the two sides of the film will always be opposite each other. If the roll is wound with the concave side in, the spokes will be alternate. The spokes seen on one side of the roll will never be opposite those on the other side of the roll.

Embossing.—Embossing was a common defect prior to the advent of the rear type shutter, which came into use at about the same time as did the sound movies. It has always been considered an important defect from the point of view of projection quality. It is obviously due to differential heating of portions of the image due to varying densities throughout the image. The blacker portions get hotter and are shrunken by the heat. Sometimes this effect is most pronounced at the frame lines, when it becomes known as frame-line embossing. During the experiments discussed in the preceding paper,¹ considerable heavy embossing was produced by the extreme arc temperatures used, but in no case was the embossing sufficient to cause any focusing difficulties in the film. Measurements of the actual depths of the embossing gave no values higher than 0.0003 inch, which is well within the range of the depth of focus of the projection lenses. Although it may possibly be that under certain circumstances embossing may increase the tendency of film to show in-and-out of focus effects, we have never found a single case of embossing that by itself gave focusing difficulties. One fact was observed, however, that fresh film, and especially film not thoroughly dried, tended to emboss more than well seasoned and dried film. Since it is also a fact that insufficient drying and seasoning tends to

produce in-and-out of focus troubles from other causes, we sometimes find that film that has been embossed has also shown in-and-out of focus troubles.

Flute or Long Edges.—The fourth type of film distortion, flute or long edges, is now seen more often with safety film than with nitrate film. A typical example of flute or long edge film is shown in Fig. 2. It is caused by shrinking the center of the film without shrinking the edges or, conversely, by stretching the edges.

(a) *Flute from shrinkage of the center of the film:* When film, especially safety film, is projected repeatedly at high heat intensities, the center tends to shrink more than the edges, causing a particular type of flute often known as "twist," since a strip of film stretched between two points gives the appearance of being twisted.

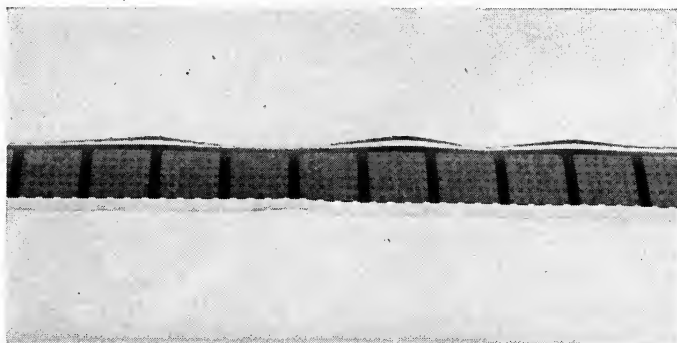


FIG. 2. Flute, or long edge, in cine film.

(b) *Flute from stretching the edges of the film by means of recessed rolls:* The edges of the film are often stretched in processing machines by pulling the film too tightly over recessed rolls while the film is wet or while it is hot.

(c) *Flute from stretching the edges of the film by the use of twisted strands:* Occasionally processing machines are designed in which the film is turned between each pair of rollers so that the emulsion side will never be in contact with the rollers. If the distance between the rollers is too short this twist puts an additional strain upon the edges of the film which often produces flutes.

(d) *Flute from stretching the edges of the film through swelling of the edges:* Flute is sometime produced in raw film if a tightly wound roll is exposed to very high humidities. Moisture is absorbed by the

edges of the film but does not travel far into the center. This means that the edges increase in thickness and each layer builds up on the one under it. Even though this thickening of a single layer of film may amount to only 0.00001 inch, there are, nevertheless, 650 layers in a 1000-ft roll of film. The increased thickness of each layer builds up on those below it so that the edges of the roll will have a diameter 0.0065 inch greater than the center and this increased diameter can occur only by stretching the edges of the film.

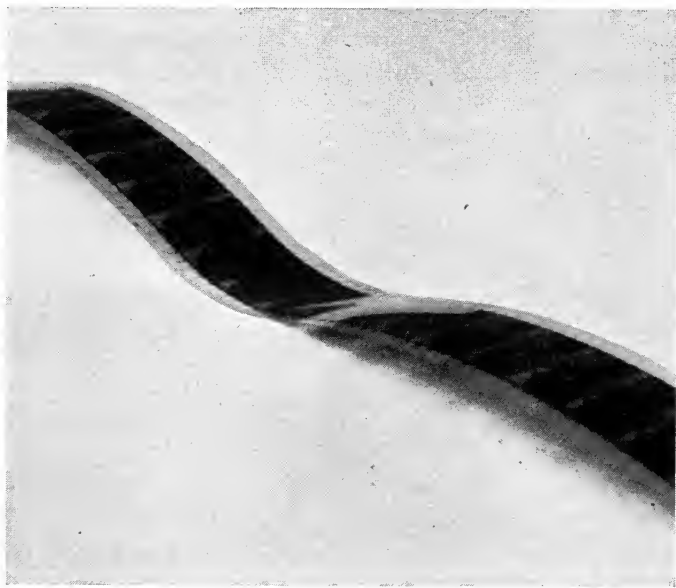


FIG. 3. Buckle, or short edges, in cine film.

Buckle or Short Edges.—The kind of distortion that has caused by far the greatest amount of trouble with 35-mm film is short edges. At the Eastman Company the term “buckle” is reserved entirely for this type of distortion, although in the trade almost any type of distortion is frequently referred to as “buckle.” Fig. 3 shows a typical example of buckle produced by short edges. It is ordinarily produced whenever a film containing a sufficient amount of water or residual solvent is wound tightly and permitted to dry so rapidly that the moisture can not diffuse from the center toward the edges as rapidly as it is taken away from the edges. The edges shrink as

they dry and may become permanently distorted. The effect is worse with film having a high potential shrinkage than with modern low shrink film, but even this film can be buckled due to moisture losses alone if conditions are right.

The use of ordinary cardboard boxes caused by the shortage of tin for shipping film from laboratories to exchanges offers ideal conditions for the formation of buckle. The freshly processed film, often in equilibrium with 50-60 per cent relative humidity, often may be exposed to humidities as low as 10-15 per cent due to the high moisture permeability of the cardboard. Experiments have shown that conditions such as described above will almost invariably buckle moist film, whereas film that has been thoroughly dried in processing will not buckle as readily. If the film, before being placed in plain cardboard containers, is wrapped in an envelope of a highly moisture-resistant paper, this tendency to buckle is practically eliminated. New types of cardboard boxes in which a highly moisture-resistant layer is incorporated in the box itself will probably protect the film even better than these moisture-proof envelopes.

The reason why short edges are so much more likely to produce in-and-out of focus effects upon the screen than any other kind of film distortion is that these short edges always leave a fullness in the center of the film that produces an "oil-can" effect. The center of the film is free to bend in one direction or the other. It is this uncertainty as to the direction in which it will bend that leads to the in-and-out of focus effect upon the screen. Film showing in-and-out of focus due to this particular effect can sometimes be corrected by changing the moisture content of the film so as to give it a potential tendency to curl in either one direction or the other. As long as it always curls in the same direction while it is in the gate, no in-and-out of focus will be observed. Such film can further be corrected by stretching the edges. This can be done by passing the film over an internally heated flat roller which shrinks the center and stretches the edges slightly.

It is our hope that this discussion will not only help to clarify the nomenclature of different types of film distortions, but that by helping us to understand the causes of these distortions, will result in better projection and better entertainment.

REFERENCE

- ¹ CARVER, E. K., TALBOT, R. H., AND LOOMIS, H. A.: "Effect of High-Intensity Arcs upon 35-Mm Film Projection," *J. Soc. Mot. Pict. Eng.*, **XLI** (July, 1943), p. 69.

CARBON ARC PROJECTION OF 16-MM FILM*

W. C. KALB**

Summary.—Characteristics of the high-intensity arc as applied to the projection of 16-mm film are described. Carbon trim, quality of light, magnification, optical speed, power of the projection lamp, and the intensity and distribution of the screen light are also discussed.

Projection of 16-mm film has passed beyond the limitations of the living room and the small classroom. It is now shown before groups of such size that enlargement to a screen image several feet in width is essential to satisfactory presentation. This has created the need for a large volume of projection light to provide the recommended level of screen brightness, a need that has been met in a highly satisfactory manner by the adaptation of the high-intensity carbon arc to 16-mm projection.

HIGH-INTENSITY PROJECTION LAMP

The projection lamp developed for this purpose¹ is a direct-current lamp operated through a rectifier from a 110-volt, single-phase, a-c supply, with a current demand of less than 15 amperes from the supply line. The 6-mm × 8-inch positive carbon and 5.6-mm × 6-inch negative² are designed to operate at 30 amperes d-c with 28 volts across the arc. The burning life of this trim is approximately one hour, ample for the projection of a 2000-ft, 16-mm reel at sound speed of 24 frames per second.

Fig. 1 shows the spectral energy distribution of the light from this arc. The composition of the positive carbon core is somewhat different from that of high-intensity positives used for 35-mm projection, increasing the proportion of light emission at longer wavelengths.

* Presented at the 1942 Fall Meeting at New York, N. Y.

** National Carbon Company, Cleveland, Ohio.

This modification is made to adapt the color-quality of the light to color-film processed for projection by incandescent light, which is customary in the production of 16-mm color-film. Color-temperature of the screen light is approximately 4450°K, giving excellent color reproduction.

The lamp mirror is designed to focus the arc crater image at the film aperture with a magnification of $4\frac{1}{2}:1$ which effectively covers the aperture. The beam divergence is sufficient to fill the 2-inch, $f/1.6$ lens extensively used for 16-mm projection.

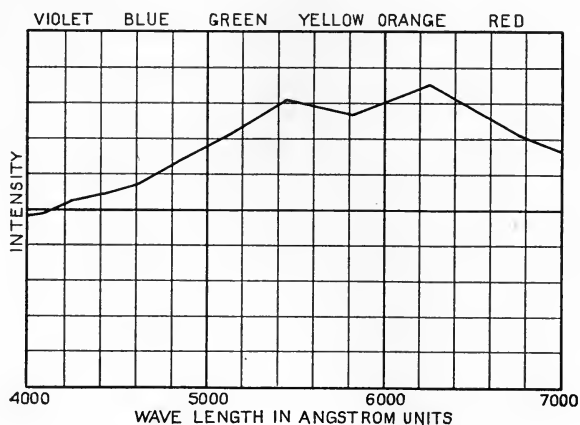


FIG. 1. Spectral energy distribution of light projected on screen from the high-intensity carbon arc developed for 16-mm projection.

SCREEN LIGHT

This high-intensity arc lamp, operated with a 2-inch, $f/1.6$ lens but without shutter, film, or heat filter, projects 2300 lumens to the screen. A representative figure for shutter transmission on commercial types of 16-mm projectors is 60 per cent, and 80 per cent is a representative transmission factor for the type of heat-filter used on 16-mm carbon arc projectors. The screen light available with an $f/1.6$ lens, shutter running and filter in place, is therefore about 1100 lumens. This is obtained with 80 per cent side-to-center distribution of screen brightness, which is about the optimum of good projection practice. The corresponding screen illumination with other lenses, calculated on the basis of relative f values, is about 700 lumens with

an $f/2.0$ lens and, with an $f/2.8$ lens, about 360 lumens. Some projectors have no heat-filter but use a rear shutter, or blower, or a combination of the two, to maintain low film temperature. With this construction somewhat greater screen illumination may be expected, other factors being equal.

Calculated values are given in Table I showing, for various widths of screen image, the brightness in foot-lamberts at the center of the screen obtained under the stated conditions with high-intensity carbon arc projection. The figures given above for screen illumination are used as the basis for this table, assuming 80 per cent side-to-center distribution of the light on the screen.

TABLE I

Foot-Lamberts at Center of Screen Image of Specified Width

Matte surface screen of 75% reflectivity
 Shutter running—transmission 60 per cent
 Heat-filter of 80 per cent light transmission
 No film in projector

Width of Screen Image (Feet)	Foot-Lamberts at Center of Screen		
	2-In., $f/1.6$ Lens	3-In., $f/2.0$ Lens	4-In. $f/2.8$ Lens
4 $\frac{1}{2}$	63.0	40.0	20.6
5	51.0	32.5	16.7
6	35.5	22.5	11.6
7	26.0	16.6	8.5
8	20.0	12.7	6.5
9	15.75	10.0	5.15
10	12.75	8.1	4.2
11	10.5	6.7	
12	8.85	5.65	
13	6.9	4.4	
14	6.5		
15	5.65		
16	5.0		

LENSES

Lenses listed as available on carbon arc, 16-mm projectors range from $\frac{3}{4}$ inch to 4 inches in focal length. The sizes usually supplied as standard equipment are 2-inch, $f/1.6$ and 3-inch, $f/2.0$. Structural limitations on some projectors necessitate the use of approximately the same effective diameter for lenses of all focal lengths so that increase in focal length is accompanied by decrease of lens speed. However, projectors are available with lenses of $f/1.6$ speed in focal lengths ranging from 2 inches to $3\frac{1}{2}$ inches.

The use of a projection lens with focal length greater than the 2-inch or 3-inch lens usually supplied with 16-mm projectors is seldom necessary although it may occasionally be advantageous in locations where seating arrangement, shape of room, permanent projection booth, or other condition necessitates a long throw from projector to screen. Increase in length of throw with a given lens increases the width of the screen image proportionately and may result in a larger image than is desirable. Furthermore, the screen brightness is decreased in inverse proportion to the change in area of screen

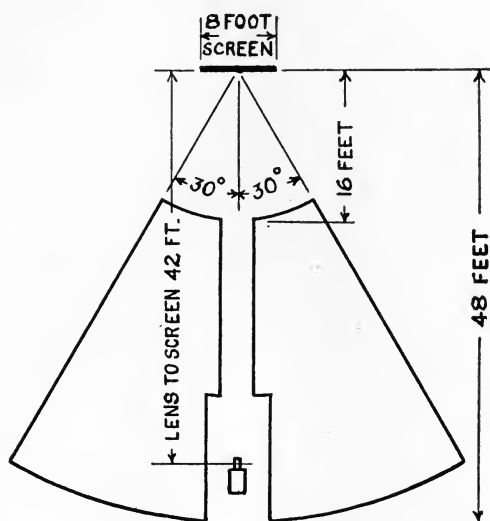


FIG. 2. Seating plan for 8-ft screen; capacity 220.

image. Increase of focal length of lens, on the other hand, allows the throw to be increased in proportion to the change in focal length, without changing the size of the screen image. However, if the lens of greater focal length is also lower in speed (f /value), less light will be thrown on the screen. Should the resulting screen brightness be below the recommended level it is usually preferable to seek some means of locating the projector closer to the screen to permit use of the standard projection lens.

The normal optical speed of the 16-mm carbon arc projection lamp being $f/1.6$, little is gained by using a projection lens of less than 2-

inch focal length in order to obtain higher lens speed and more light on the screen. Some increase in optical speed of the lamp can be obtained, to make effective higher lens speed, by decreasing the distance from mirror to aperture and increasing that from mirror to arc. However, the principal occasion for using a lens of less than 2-inch focal length is where the projector must be located relatively close to the screen and a projected light-beam of wide angle is needed to obtain the desired width of screen image.

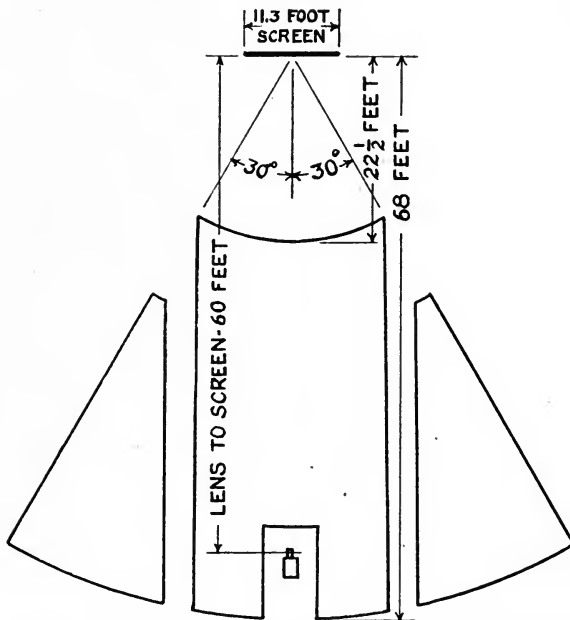


FIG. 3. Seating plan for 11.3-ft screen; capacity 412.

Data on screen light given throughout this paper are based upon untreated lenses. Lenses that have been treated to reduce reflection losses and improve the transmission factor are not commercially available for 16-mm projection at the present time. However, carbon arc projection of 16-mm film with untreated lenses meet recommended standards of projection practice for audiences of such size that situations are seldom encountered in which there is need for treated lenses to provide a satisfactory intensity of screen illumination.

SIZE OF AUDIENCE

The SMPE Committee on Non-Theatrical Equipment has recommended³ certain procedures and conditions to be observed in the presentation of 16-mm motion picture film to provide a picture that can be viewed to good advantage by everyone present. Among the recommendations made are the following:

(1) Distance of farthest spectator from screen should not exceed 6 times the width of screen image.

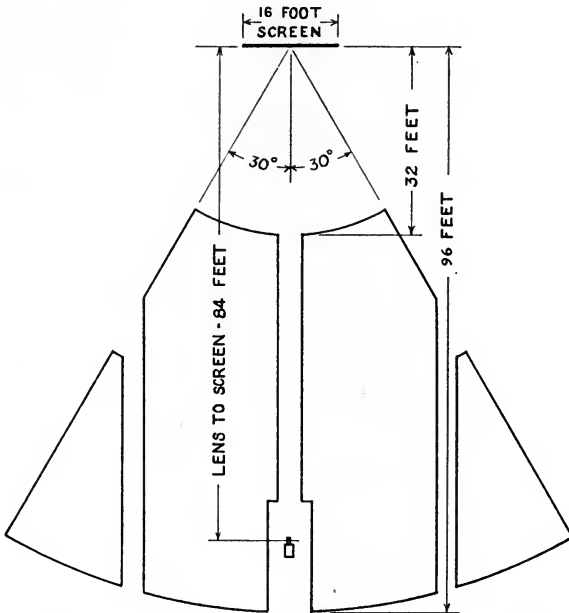


FIG. 4. Seating plan for 16-ft screen; capacity 856.

(2) Distance of nearest spectator from screen should not be less than twice the width of screen image.

(3) Viewing angle of no spectator should be greater than 30 degrees.

(4) Optimum screen brightness, 10 foot-lamberts measured with shutter running but without film.

(5) Limits of screen brightness, not more than 20 foot-lamberts or less than 5 foot-lamberts, measured as above.

(6) Color-temperature of the light delivered to the screen to be in the range from 3000° to 4700°K.

(7) The use of matte type of screen "in all cases where a projector of adequate illuminating power can be obtained."

The report further points out that a 2-inch, $f/1.6$ lens fills the screen at a distance equal to $5\frac{1}{4}$ times the screen width.

From Table I it may be observed that, with a matte surface screen of 75 per cent reflectivity and a 2-inch, $f/1.6$ lens, high-intensity carbon arc projection of 16-mm film provides the maximum recommended level of screen brightness with an image 8 feet in width and fills a 16-foot screen at the minimum limit of brightness. The calculated image width at optimum brightness of 10 foot-lamberts is 11.3 feet. Color-temperature of the light is within the range recommended by the committee.

Figs. 2, 3, and 4 represent seating plans conforming to the recommended limits of viewing angle and distance from screen for the three conditions of screen width and brightness named in the preceding paragraph. Seating capacities are based upon the use of 20-inch seats, 32 inches back to back, with a limit of 14 seats between aisles as prescribed by the laws of some states. Fig. 2 shows that advantageous presentation of 16-mm film can be made with high-intensity carbon arc projection, at maximum recommended screen brightness, before an audience of at least 220 persons. Presentation at optimum screen brightness can be made before 412 seated spectators with the seating plan shown in Fig. 3 and, at the acceptable screen brightness of 5 foot-lamberts, before an audience of 856 seated as indicated in Fig. 4.

Carbon arc projectors are now available from several of the larger manufacturers of 16-mm projection equipment. The increased screen size that can be adequately illuminated by these carbon arc projectors greatly extends the utility of 16-mm film for educational, commercial, and other purposes. It makes practicable the showing of a 16-mm picture before a comfortably seated audience of several hundred under conditions conforming to the best standards of projection practice.

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¹ STRONG, H. H.: "A High-Intensity Arc for 16-Mm Projection," *J. Soc. Mot. Pict. Eng.*, **XXXIII** (Nov., 1939), p. 569.

² LOZIER, W. W., AND JOY D. B.: "A Carbon Arc for the Projection of 16-Mm Film," *J. Soc. Mot. Pict. Eng.*, **XXXIV** (June, 1940), p. 575.

³ "Report of the Committee on Non-Theatrical Equipment," *J. Soc. Mot. Pict. Eng.*, **XXXVII** (July, 1941), p. 22.

THE PRACTICAL SIDE OF DIRECT 16-MM LABORATORY WORK*

LLOYD THOMPSON**

Summary.—Laboratory practice for direct 16-mm production differs somewhat from 35-mm methods. Thirty-five-mm laboratory practice is confined largely to negative-positive, and 35-mm color is done mostly by special service laboratories and not by the studio or release-print laboratories.

Direct 16-mm production calls for the reversal type of processing, the negative-positive method, and color developing. Some producers own laboratories for doing the first two, but color is processed by the manufacturer. However, independent laboratories are printing color. This paper describes how some of these processes are used in direct 16-mm production, especially when the methods differ from conventional 35-mm practices.

There have been a lot of theories expounded as to how 16-mm laboratory work should be done. A number of them have been based upon anticipation of what the film manufacturers may be able to offer in the future. But we, the people engaged in making 16-mm motion pictures in order to earn a living, can not wait until all these problems have been worked out. Sometimes we have to forget the theory as worked out by the best laboratories doing 35-mm work and use a method that will do the job even though it may not conform to theory.

This does not mean that we are not grateful for the theory as worked out by these laboratories and practiced by the producers of 35-mm film, because we are. A great many of their theories work equally well in 16-mm practice, and so the problem becomes one of when should we use 35-mm methods on 16-mm films and when should we disregard the methods and theories and start using some other method of production or laboratory procedure. The answer is probably quite simple. Begin by using the procedure that is recommended, and if it does not work try something else. To say that

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such a cut-and-try method of arriving at a standard should be a standard for all time to come would be foolish. The procedures outlined in this paper have been used in actual production work and are being used today. We constantly try out new ideas and new methods and when such a method proves itself to be better or more practicable, the new procedure is adopted.

Laboratory practice for direct 16-mm work may be divided into several divisions:

- (1) Original photography.
- (2) Sound-tracks.
- (3) Prints.

Each of these may be further subdivided. We shall begin with original photography as it is known at the present time:

- (1) Black and white.
 - (a) Reversal.
 - (b) Negative and positive.
- (2) Color.

Most of the recognized 16-mm producers today use reversal film in shooting their original black-and-white pictures. However, there is a growing tendency to use Kodachrome even for black and white. In such cases the original is made in color and the black-and-white prints are made from dupe negatives. There are several things to recommend the procedure.

The arguments for using reversal film for the original picture have been listed before, but we may summarize them briefly by saying that reversal film gives finer-grained originals and excellent tone quality. Dirt spots do not show up as objectionably as on negative film, and the original film can be more easily handled and spliced because 16-mm splices made on reversal film do not show up on the screen as they do with negative film. The first cost of reversal is less. The laboratory set-up for 16-mm reversal film is well standardized throughout the world, and one can be assured of getting fairly consistent results at any of these laboratories. Sixteen-millimeter reversal film is readily accessible almost anywhere. The material lends itself well to making dupe negatives so that the original can be preserved.

Some of the objections that have been raised to the use of reversal film are that it does not have as much latitude as the negative-positive process. It is said to be more critical in exposure. The photographer does not have the corrective latitude in making the prints after

the original has been processed that he does with negative-positive. Some of these things are probably true. The film does take special handling in that the lighting must be somewhat different from that used for negative-positive film and the exposure should be as nearly correct as possible. However, this should not work any hardship on the cameraman who is working with direct 16-mm in a professional way, because he will probably be called upon to handle both black-

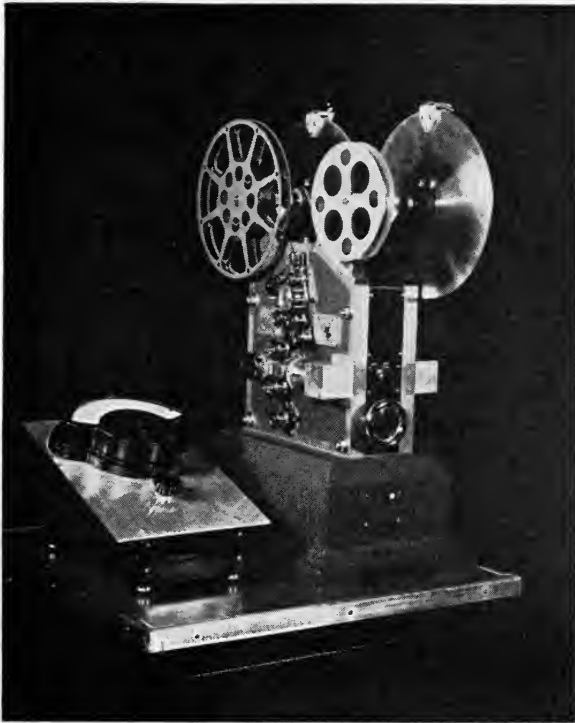


FIG. 1. One-to-one optical sound-printer for 16-mm.

and-white and color. Color is a reversal process and must be handled in much the same way as black-and-white reversal. For that reason the cameraman must be capable of using an exposure meter in such a manner that he is able to get consistent exposures, and he will also be in the habit of lighting for color-film. It is true that there is some difference in the lighting for Kodachrome and black-and-white reversal, but probably not as much difference as there is be-

tween Kodachrome and negative film. In making a black-and-white production by the reversal method the cameraman should always try to have enough film of one emulsion number on hand to do the complete job. He should decide to what maximum density he wishes the film developed in order to get the results he wants. Usually this maximum density will be approximately 2.1 to 2.3. He should then make tests with the type of film he expects to use, at different exposure levels, and have the film developed to the correct maximum density. From this series of tests the cameraman can pick out the exposure most nearly correct and thus set his exposure meter so that he can duplicate the results throughout the production. If these simple precautions are taken he should have no trouble in getting consistent results. He should inform the laboratory doing his work what he is trying to do, and it is necessary in sending such black-and-white films to the laboratory to enclose a note with them stating what is wanted. If the cameraman is having his film developed to a specific maximum density, he should allow enough blank film on one of the rolls for the laboratory to run an actual developing test so that they can be certain of getting the correct density. In doing professional work with 16-mm film the producer must remember that the reversal laboratories are set up to process amateur film. There are some laboratories that use automatic exposure compensation to correct exposure errors. For average amateur films this is perfectly all right, but the maker of professional pictures usually does not want this. There are other laboratories that develop to a certain maximum density and depend upon the cameraman to give the correct exposure. Both methods have their advantages and disadvantages, but the professional user will usually do better to give the film the correct exposure and then have it developed to a specified maximum density. In developing amateur film the reversal laboratory receives each day many different emulsion numbers from different customers. Some of this film may be out of date, some of it may be almost out of date, and other rolls may be fresh film. Some of it may have been stored under bad conditions and other rolls will have been kept under ideal conditions. Different batches of emulsion will vary, and as a result some of the rolls may be developed in such a way that they would not meet standards of the professional. For that reason it is a good idea to send a test strip along with each batch of film sent in for processing and to specify the maximum density to which the film is to be developed.

The criticism has been made of reversal film that it does not have as much latitude as negative-positive. Practical experience has shown that if an exposure meter is used consistently the latitude is sufficient for all practical purposes and by making light-changes in the prints the films can be evened out very successfully. Extreme under- or overexposure is, of course, very difficult or impossible to correct in printing. But this may also be true of 16-mm negative-positive. Because of its size, 16-mm film must be more nearly cor-

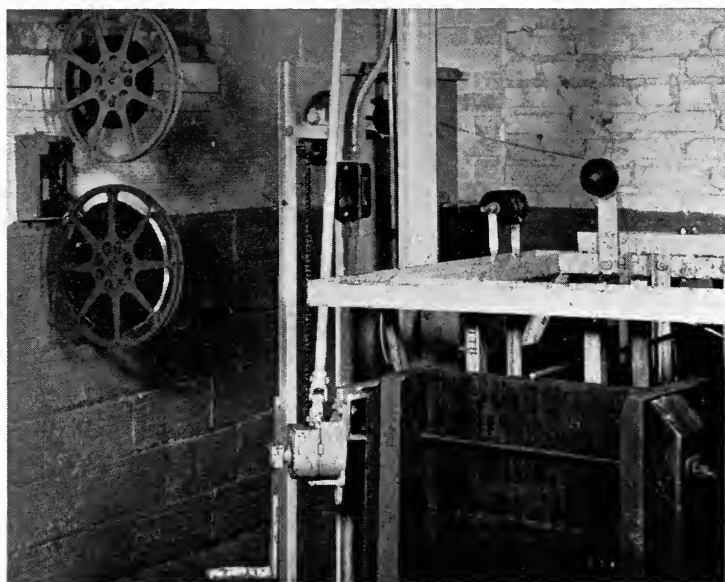


FIG. 2. Wet end of a 16-mm reversal processing machine.

rectly exposed than larger films, whether reversal or negative-positive.

The criticism has been made also that reversal films are not especially suited for shooting under adverse conditions. The statement has been made that many times it is impossible to light a subject sufficiently and it is necessary to bring it out by overdevelopment of the negative, and that this can not be done in reversal. This is not the case. There are times when the cameraman does not have enough light on the scene and yet he must make the shot. In such a case he should shoot the scene that does not have sufficient light and

keep the film separate from the rest of the film. He should also shoot some extra footage on this particular scene at the same exposure he used in making the test. He should give this to the laboratory for test and ask them to overdevelop it so as to give the best results. The laboratory can then take the extra footage and run one test or, perhaps, several tests, in order to find exactly how much the film should be overdeveloped in order to get the best results from that particular roll. This is extra work for the laboratory but most laboratories are willing to cooperate. Such tests require extra time and when something special is wanted the lab should be allowed some extra time in order to perform the necessary tests to get the best results.

While it is possible to get good results with rack-and-tank developing, automatic machine processing gives more consistent results from day to day. Most producers of 16-mm film will find it to their advantage to use the laboratory that offers machine processing. Practically all film manufacturers offer such a service, and any of the standard films on the market offer laboratory service where machine processing is available. Occasionally some 16-mm film producer will attempt to use an off-brand film or try to process a negative film as reversal, and naturally the results are disappointing. Standard-brand films should be used, and certain types of emulsions will do a better job than others. The user will therefore have to learn which emulsions give best results for his purpose and he should then try to stick with that particular type of emulsion. He should, of course, try new emulsions as they are offered from time to time, and there are times when the cameraman wants some effects that can be made only by using a special emulsion. He may even want to use positive film and reverse it.

Most of the direct 16-mm producers have probably started with the idea that the way to shoot 16-mm commercially would be to use negative film and make positive prints from it just as they do in Hollywood. There has been a great deal of effort spent in trying to develop a laboratory procedure that would be entirely satisfactory for 16-mm commercial work done in this manner. Some very good work has been done, but there are still a number of things about the process that make it impracticable for most commercial purposes. The time may come when these defects will be corrected.

A great number of developers have been tried with negative film. There are the common borax-type formulas which are well known in the 35-mm industry. There have been other special formulas in-

volving the use of paraphenylenediamine and various combinations of chemicals. These formulas have been worked out in an attempt to get fine-grain quality from original negatives that would match the fine-grain characteristics of reversal film. The use of fine-grain positive has done a great deal toward reducing the graininess. Also, the original negative can be developed to a lower gamma and the positive print to a higher gamma, which makes for finer grain.

In developing 16-mm negative film it is extremely important that the film be developed to the correct gamma. It is important also that the processing be very clean because dirt spots become very objectionable white spots on the positive print. Negative film is also



FIG. 3. The testometer, used for checking timing. The left side contains a time-scale sensuometer.

very susceptible to scratches and any scratch, no matter how slight, either on the back of the base or on the emulsion side, will show up on the positive print as an objectionable white line.

Because 16-mm negative film is so susceptible to scratches and dirt and because the splices made in negative film show up as objectionable white lines on the screen, it is extremely difficult to handle in regular production work. The same precautions should be observed in shooting negative film as in shooting reversal. That is, it should be properly exposed, different emulsions should not be mixed together in the same production unless it is absolutely necessary, and the producer should have the full cooperation of the laboratory in

getting the most out of his negatives. Machine processing is highly desirable.

At the present time the only commercial process for shooting 16-mm color originals is Kodachrome. Kodachrome is developed only in the laboratories of the manufacturer of the film, and here we might say the customer has no control over the laboratory practice in developing the film. We might also assume that the customer needs to take no special precautions because the laboratory procedure on Kodachrome will be consistent from day to day, and thus the results will be the same. This is not exactly true. We in the 16-mm business quite frequently see films that have been shot by some amateur



FIG. 4. Using the testometer as a sensitometer.

photographer to be used in a commercial film. He has taken no special precautions as to using one emulsion number throughout the picture or through one particular sequence, or as to sending all of the picture, or all of the pictures in a sequence, for processing at one time. As a result we quite frequently see pictures in which the color balance changes considerably. On the other hand, we have shot a number of Kodachrome pictures and have not been annoyed with this change in color balance to any degree. However, there are certain precautions to be observed. If possible, we usually try to shoot an entire picture on one batch of emulsion or at least we try to shoot one particular sequence on one particular emulsion number. If possible we also

like to shoot one entire sequence or an entire picture and send it in for processing all at one time. The laboratory that develops our Kodachrome film is aware of the fact that nearly all the Kodachrome which we send for processing is of a commercial nature, and these films are never run until they have had a chance to see the work coming from the machine and had a chance to check it to be sure that the color balance is correct. If the color balance is slightly off, the films are held until it is as nearly correct as possible, and then the films are run through. The color balance is never very far off, because in nearly all cases the films are within very acceptable limits. If the picture is to be used for commercial purposes it is desirable that these limits be held within as close tolerances as possible. Here again we have found the laboratories perfectly willing to cooperate in every way provided we tell them what we are trying to do.

Just as in 35-mm practice, there are two types of sound-tracks used in direct 16-mm. However in the 16-mm field variable-area predominates. In direct 16-mm there are three types of variable-area tracks used at the present time. They are:

- (a) Negative tracks.
- (b) Direct positive tracks.
- (c) Reversal tracks.

Variable-area negative tracks are used for:

- (1) Printing with original negatives.
- (2) Printing with dupe negatives.
- (3) For making positive prints for printing with Kodachrome prints or black-and-white reversal prints.

Variable-area direct positive tracks are used for:

- (1) Printing directly to Kodachrome.
- (2) Printing directly to black-and-white reversal tracks.
- (3) For re-recording.
- (4) For printing negative tracks where it may be necessary to have several negative tracks.

Variable-area reversal tracks are used for:

- (1) Single-system sound.
- (2) Re-recording purposes.

Variable-area tracks are usually developed in regular positive developer although there have been special formulas developed for processing variable-area tracks. Since processing machines are usually set up with positive developer and since these developers are in constant use, it is comparatively simple to keep the developer at

the correct potential at all times. Regular I**Ib** sensitometric strips can be run through with the processing during the day and these strips checked to be sure that the developer is in proper condition before running sound-tracks. If a special developer is used for sound-track developing only, it is necessary either to change developers in the tank or to have a special tank for sound-tracks only. In either case the developer is not in continuous use, and since there is probably no laboratory with enough direct 16-mm sound-tracks to keep it running constantly, it is necessary that a certain portion of the day be picked for running sound-tracks. If the developers must be changed it is necessary to check their temperature; also to run either a test of the sound-track or a sensitometric strip before actually processing the film. This takes a great deal of time and it is questionable as to whether this procedure helps the final result. If yellow-dyed recording stock is used with blue light (4000 to 4500 angstroms: Corning 597) for making the original sound-track, the usual procedure is to develop the negative tracks to a density of 1.8 to 2.0. Gamma is usually 1.8 to 1.85. Positive prints made from such negatives on fine-grain stock and developed to the proper gamma and density will give good reproduction and also improve the noise level of the positive track.

Direct positive tracks are not in general use either in 35-mm or direct 16-mm productions. By direct positive track is not meant reversal track, but direct positive track produced optically. The track is developed as an ordinary sound-track, but instead of getting a negative track we have a positive track, which can be used either for play-back or for printing by the black-and-white reversal method or with Kodachrome. It is necessary to have a special galvanometer for this type of track. According to theory such track does not lead to good results. However, we have not found that to be exactly true. Since yellow-dyed stock has been available for recording sound in direct 16-mm, it has been possible to make good direct 16-mm positive tracks without very much difficulty. Such tracks must be properly exposed and developed if good results are to be obtained. The density becomes rather critical. We have used such tracks for a number of purposes: for recording music when the music was to be re-recorded on another direct positive or negative track for printing; for recording original voice which was to be used for re-recording before printing; and for direct recording when the recording was to be printed with Kodachrome or with black-and-white reversal prints. We have also made direct positive tracks, and then dupe negatives

from them for making positive prints. We have been told many times that some of the things we are doing are entirely wrong and we simply should not do them that way. We have conducted a great many experiments along this line and are convinced that for a number of purposes the direct positive will work very satisfactory in direct 16-mm recording work. If the film is to be used for direct play-back or for re-recording, the density is kept at 1.2 to 1.3. If it is developed beyond 1.4 the highs usually have a tendency to block slightly. If the direct positive is to be used for printing with Kodachrome or for printing black-and-white reversal prints, the density of the direct positive sound-track can go up to 1.5, 1.6, or even higher. We have never found any particular advantage in going beyond 1.5 or 1.6, as a track of this density seems to be about as quiet in the print as one that has been developed to a higher density. (Some of the new recording stock should be developed to 1.8, 1.9, or higher.) While it is possible to make direct positive tracks on regular positive release stock, the developing becomes very critical, and for that reason we have found the yellow-dyed stock to be much more satisfactory for making this type of track, as well as for other direct 16-mm recording. Direct positive tracks are developed in positive developer the same as the variable-area negative tracks. In production work we attempt to control the exposure of the original recording so that all tracks can be developed a normal time in the developer and when different densities are wanted the exposure is changed to give that density. If emulsion numbers are closely watched and exposure lamps are carefully checked and tested before use, it is comparatively simple to get whatever density is wanted from day to day.

Producers who do not own their own laboratories and must depend upon outside laboratories for developing their original sound-tracks can get the same results if they will follow certain definite procedures. One complete session of recording should be recorded on one emulsion number if at all possible. Lamp currents should be carefully adjusted and maintained accurately. A test exposure should be left on one of the rolls of film and this roll clearly marked as to how much and where the test will be found. The density wanted on the final track should be clearly indicated. If it is necessary to change emulsions during a session, this should be clearly indicated and a test left on the new emulsion that is used. If it is necessary to change recorder lamps during a recording session, this also should be noted on the film and a test left for the new lamp as

well as the old one. All recording lamps should be checked photographically before being used. We have found that recording lamps that are supposed to be prefocused and correctly adjusted will vary as much as four or five points in density. For that reason we have made up a special jig for our recorders, and whenever we receive new lamps they are checked in this jig with a master lamp which we know gives us maximum exposure. Before doing this we had a great deal of difficulty in trying to keep our densities correct over a period of time. All new lamps are first checked in the jig and then inserted in the recorder; then a short photographic test is made of them and the density given by each of the lamps is marked on the lamp. In this way if the lamp burns out during recording it is possible to select another lamp having exactly the same characteristics, and proceed with the recording. It might seem that this is taking a lot of unnecessary care, but if the film is to be used for commercial purposes we feel that everything should be as nearly correct as possible, and it is much cheaper to make these checks than it is to make retakes. These precautions are necessary for a producer operating his own laboratory even though he has full knowledge of any irregularities that may take place. Commercial producers who send their work to commercial laboratories must take the same precautions if they expect the results to be uniform.

Variable-area reversal tracks are usually used with single-system sound recording. There are several reasons why the reversal system can not be used in place of the direct positive tracks about which we have been talking. Most galvanometers do not have enough light in them to expose positive film or yellow-dyed recording stock sufficiently for the reversal process. Even though the galvanometer may have enough light for exposing the stock for reversal processing, the exposure and the developing become very critical. Unless the exposure and the developing are absolutely correct on positive film or recording stock, the sound either loses a great deal of volume because the clear portions do not clear out completely, or the highs are cut off by overexposure or incorrect developing. If panchromatic film or Kodachrome is used for recording sound by this method, these defects are not nearly so noticeable. In this case the exposure is not so critical although enough exposure should be given to clear out the clear portions of the track, otherwise the volume level becomes very low and the background noise becomes objectionable. The danger of overexposure is not so great when this type of film is used. It is

perfectly satisfactory to record sound on panchromatic film or on Kodachrome when the picture is being taken at the same time. However, most people will not want to use regular panchromatic film for recording the sound only, as it will be somewhat expensive and the results will not be as good as is obtained with, for instance, a direct optical positive. Such film can be used for re-recording purposes quite satisfactorily but it is not suitable for re-printing by the reversal system. Sound made by the reversal system has a slight tendency toward distortion due to the spreading of the light-beams and the procedure used in reversal processing. Therefore, if an original reversal sound-track is printed again by the reversal method, this distortion tends to build up and become rather objectionable. Single-system sound shot on Kodachrome is also quite satisfactory when the proper exposure is given and when the sound is used as a direct playback. Such sound-tracks are not suitable for printing to another Kodachrome duplicate. If such sound-tracks must be re-printed, the best method at the present time seems to be to re-record the sound to the black-and-white track and then print from that. Re-recording the sound-track directly on the print is also satisfactory, but in such case type *A* stock must be used instead of duplicating stock, as the dupe stock is too slow to be used in most recorders.

Variable-density has not been used a great deal in direct 16-mm work. Probably the widest use of variable-density in 16-mm has been with single-system cameras. It has been necessary that these cameras use negative film as they were unable to get enough exposure of the reversal type of emulsion to get a sound-track. Since practically all the variable-density sound has been made with single-system cameras, it does not seem that anyone has done very much research on the developing and printing of variable-density direct 16-mm sound. Since most people shooting single-system variable-density sound are interested in getting a good picture, negatives are nearly always developed to get the most out of the pictures and let the sound take care of itself.

After the original photography has then been shot and the original sound has been made there is then the question of getting prints, and the question of getting good prints has been one of the biggest problems in the 16-mm field. However, this problem has been pretty well solved during the past few years and practice is becoming fairly well standardized. We shall consider first the problem of black-and-white prints.

The first print wanted from an original is usually a work print. If the original is reversal or Kodachrome, a reversal black-and-white work print is made—all on one light. An inexpensive grade of film such as positive is used for printing, and this is reversed. This gives a positive image which is easy for the editor to work with. Some originals are now shot on stock with edge numbers in which case they can be printed on the work prints. This is the most satisfactory method of editing except that the use of edge-numbered stock for originals is not yet universal. Rush prints, as they are known in the 35-mm field, are usually not used in 16-mm work. Originals are usually projected for this purpose, and then those scenes that are to be used are cut out, spliced, and a work print made.

Suppose the original was made on black-and-white reversal film or Kodachrome. The first method of making black-and-white release prints from original reversal film was the reversal process. There were, of course, dupe negatives, but the early dupe negatives were far from satisfactory. The prints obtained with the reversal system were good enough that most persons were not able to tell them from originals. For that reason the reversal process was used almost exclusively for several years in making black-and-white prints from reversal originals, as well as in making sound-prints. The method is still capable of giving excellent results, and when only a few prints are wanted from an original it is probably the most satisfactory and the most economical method of making them. The procedure for making black-and-white reversal prints is well standardized. They can be turned out in the shortest possible time and there is no added expense of making a dupe negative.

The most satisfactory solution to printing direct 16-mm sound seems to be the one-to-one optical sound-printer. It gives good definition, and there is no shrinkage or creepage problem. The results are consistent from day to day. The printer can be used for printing all direct 16-mm tracks. If sound is to be added to black-and-white reversal prints it is necessary to have a positive track of some sort or other. This positive track can be a positive from a negative or it can be a direct optical positive. The density of the track should be 1.5 or more; in any event the density of the original track for making reversal prints should be quite high. If a reversal print is made of an original track of low density, there is a tendency to lose considerable volume. In order to avoid losing this volume it is necessary to print with enough light to clear out the clear portions com-

pletely. With this rather strong printing light the dark portions of the track also have a tendency to become lighter in the print, and if the original is light at the beginning this will be accentuated in the print. The track is likely to become noisy either from a lack of density in the dark portions or because of density in the clear portions. However, original sound-tracks having a density of 1.5 or better print very satisfactorily on reversal film. Printing reversal tracks from original optical positive seems to have the same cancelling effect upon distortion as printing negatives to positives.

If a number of black-and-white prints are wanted from an original black-and-white reversal film or from Kodachrome film, the cheapest and most satisfactory method of obtaining them at the present time is by making a fine-grain dupe negative on panchromatic duplicating film. This dupe negative is then used for printing positives. The most satisfactory material for printing the positives at the present time seems to be the fine-grain positive films that are available. In making a 16-mm dupe negative it is necessary to be especially careful that no blemishes or dirt occur in the processing, since they will show up in the final print and be quite objectionable. It is almost necessary to use a step printer with pilot-pin movement in making these dupe negatives if proper contact and screen steadiness are to be achieved. After a steady dupe negative is made, it can then be printed on a good continuous printer with satisfactory results. Continuous printers seem to be quite suitable for making any print where several printing processes are not required.

At this point it might be well to discuss the construction of 16-mm printers and print rooms. Since several types of film are used and since they can be worked under different safe-lights, we have found it advantageous to work each printer in a separate room. Each operator can use a safe-light suited to the stock he is using without interfering with any other operator. In some cases we have found it advantageous to use white-light loading-dark-room printing printers. Original films are usually edited to lengths of 390 feet on 400-ft reels. Our printers are all constructed to take these reels and we use cores only for the raw stock. By keeping originals on reels it makes them easy to handle, store, and check.

In order to make consistently good dupe negatives it is necessary to use sensitometric strips for checking density and gamma. If the final release prints are to be of uniform density throughout, it is necessary to use some sort of machine for checking light-changes. This

check is probably more important in making dupe negatives from 16-mm originals than it is in 35-mm work. In our own laboratory we use a machine called a testometer, which was manufactured especially for us by the Baker Motion Picture Apparatus Company. It is a combination time-scale sensitometer and light-testing machine. Unlike many machines which make exposure tests on alternate light changes on the printer board, this machine has been built to cover a complete range from one end of the scale to the other on our particular printers.

It is important that this machine be used for timing, instead of inspecting the original film visually and then having the operator judge the correct light-change, because an original picture made on 16-mm reversal film may have a number of different types of film in it. It may have several different brands of reversal stock developed in different laboratories. This is not recommended, but such things happen. It may contain titles made on positive film. It may contain shots taken from 35-mm film and reduced to 16-mm positive film.

The reversal process has a tendency to deposit a slight yellow tone in the gelatin of the film. This strain will vary somewhat in the same laboratory from day to day. It will naturally vary from day to day with different laboratories and also with different brands of film. There may be days when there is practically no stain. Different brands of reversal film will also have different tones due to the characteristics of the emulsion. Usually the finer-grained films have a tendency to be slightly on the brown side. All these things affect the printing light, and the operator will have a very difficult time distinguishing between various tones and setting his printer light correctly. These tones are usually not deep enough to be objectionable when the picture is projected but they are deep enough to affect the printing light considerably.

The procedure used in our laboratory is to make these testometer exposures on reversal duplicating film and then have them developed to normal density. The testometer strips are then projected on a small screen with the same intensity of illumination as would be used on a normal-size screen. From these tests we are able to pick the best exposure from each test strip of each scene, and a dupe negative made in this manner will usually print on one light-change. Panchromatic duplicating film is exposed in our laboratories at the same printing light as reversal duplicating film. This

machine can be used also for checking color merely by using the light of the proper color-temperature with the correct filter.

Once the correct dupe negative has been made from an original black-and-white reversal or colorfilm positive, prints are then made; and if the negative has been correctly made the positive prints will be of excellent quality with good detail, good tone quality, and fine grain. Dupe negatives, like original negatives, are very susceptible to dirt and scratches, and the utmost care must be used in handling them because the slightest scratch or piece of dirt will show up in the final print as an objectionable white streak or spot. If such a negative is ruined or worn out, another negative can, of course, be made from the original, and one can start all over again. When a large number of black-and-white prints is wanted, a dupe negative has a definite advantage over prints by other methods. If the original has been edited with masks for trick effects, these masks are run at the same time. The effects will then be in the dupe negative and will appear in the positive prints.

If original negatives are used for making positive prints, it is necessary to time them for light-changes and then print them just as one would print from dupe negatives. It is difficult to say how many prints can be made from an original negative before it becomes worn or scratched, as this depends entirely upon the handling of it and the type of printer used. The procedure for handling original negatives and dupe negatives, and the printers used for printing them, are continually being improved, and as they are improved more prints can be made from each negative.

At the present time the most successful method of making color-prints from original Kodachrome is to print on Kodachrome duplicating film. As yet, the results of making a master print corresponding to a dupe negative and making prints from it are not entirely satisfactory. That, of course, would be the ideal way of making prints, but to date all Kodachrome prints are made directly from the original when the best quality is desired. When various laboratories began to print Kodachrome, one of the biggest worries was how many prints could be made from the original before it was worn out. We do not yet know the answer, but there have been instances where 250 prints have been made from an original. There is one thing peculiar about printing Kodachrome. The base side of the film can become quite badly scratched and abraded, but most of the marks do not show up in the print. Small scratches or abrasions on the base that

would be utterly disastrous to a black-and-white dupe negative do not seem to print on Kodachrome. It is only when there is dirt on the film or when the scratches become very deep and black that they seem to show up on the print. Ordinary 16-mm printers that have been used for black-and-white printing only must usually be converted before they can be used for printing Kodachrome. Kodachrome duplicating film takes a great deal more light than any other film used in 16-mm printing. Some printers can be converted to give the extra amount of light, and if the printer is still used for printing black-and-white, some method must be used for reducing the light for the other stock. This can be done by changing lamps or by using neutral density filters. Instruction for balancing the light for Kodachrome printing can be obtained from the Eastman Kodak Company, but such directions will probably serve only as a guide in setting up any particular printer. We have set up several printers for Kodachrome printing and in each case it has been necessary to use a different filter set-up, even though the lamp temperatures were the same, as nearly as we could tell with the color-temperature meter and by referring to the charts of the lamp manufacturers. Once the printer has been balanced for color-printing, it is usually a good idea to print tests on it over a period of a week or two and have them processed on various days before putting the printer into actual production. If this is done it may be found that slight additional corrections are desirable to give the best average results. We have already discussed sound-printing on black-and-white reversal film. The printing of sound on Kodachrome film does not seem to be as critical as on black-and-white. Optical printers seem to be the most satisfactory for the sound, and the additional contrast gained is an advantage. Sound printed by contact on Kodachrome can also be quite satisfactory.

A direct optical positive, or a positive from a negative will make a good Kodachrome print. The best density of this track seems to be 1.4 to 1.6. A few exposure tests should be run on the Kodachrome and after processing the print should be played on several reproducing units. Such tests should be conducted at periodic intervals.

SOCIETY ANNOUNCEMENTS

FIFTY-FOURTH SEMI-ANNUAL TECHNICAL CONFERENCE OF THE SOCIETY

At the meeting of the Board of Governors held at the Hotel Pennsylvania, New York, on May 3rd, it was decided to hold the Fifty-Fourth Semi-Annual Technical Conference of the Society at Hollywood. The headquarters will be the Hollywood-Roosevelt Hotel, and the dates October 18th to 22nd, inclusive.

The Chairman of the Papers Committee for the Meeting will be Dr. C. R. Daily. The personnel of the Papers and other Committees will be announced in the next issue of the JOURNAL.

Those intending to submit papers for the Conference should communicate as early as possible with Dr. Daily, at Paramount Pictures, Inc., 5451 Marathon St., Hollywood, Calif.

MID-WEST SECTION

Due to the declining activity of the Mid-West Section of the Society during the past several years, the Board of Governors, at their meeting at New York on May 3rd, took action to discontinue the Section.

There will thus be two Local Sections of the Society: (1) the Atlantic Coast Section, comprising members of the Society resident in the Eastern and Central Standard Time Zones, and (2) the Pacific Coast Section, comprising members resident in the Mountain and Pacific Standard Time Zones. Members of the former Mid-West Section will be affiliated with either the Atlantic Coast Section or the Pacific Coast Section according to their places of residence.

MAILING OF NOTICES TO MEMBERS OF THE ATLANTIC COAST SECTION

As the territory included by the Atlantic Coast Section of the Society extends from Maine to Florida and includes the Eastern and Central Standard Time zones (as the result of the discontinuance of the Mid-West Section), many of the members of the Section find it impossible to attend the monthly meetings and other functions. The situation has been considerably aggravated by the present difficulties of transportation.

For these reasons, as well as for reasons of economy, the Board of Governors, at the meeting held on May 3rd at New York, felt that notices of meetings, routine letters, and other material should be sent only to members of the Section residing in the New York metropolitan area, since it is from this area that the meetings draw practically all their attendance.

However, the Board provided also that members not residing in the New York metropolitan area but who wish to receive such notices, *etc.*, may have their names continued upon the mailing list of the Section by writing to the office of the Society, at the Hotel Pennsylvania, New York, N. Y.

THE ASSOCIATION FOR SCIENTIFIC PHOTOGRAPHY

The following announcement concerning the formation of The Association for Scientific Photography has been received from Mr. Donald McMaster, of Kodak Ltd., England:

Within recent years there has been a very marked increase in the use of photography as a scientific instrument in applied science and industry. It is felt that the majority of workers in these fields are working quite independently of others similarly engaged and that a new organization catering for their special photographic requirements would be of considerable value.

An Association for Scientific Photography has accordingly been formed, membership of which is open to any person actively engaged or interested in the use of kinematography or photography as a scientific instrument.

The Committee of the Association consists of the following persons: Prof. J. Yule Bogue (*Chairman*), S. Boyle, Miss K. C. Clark, G. A. Jones, E. H. Le Mon, Dr. H. Mandiwall, C. D. Reyersbach, G. H. Sewell, R. Mc. V. Weston (*Organizing Secretary*).

The aim of the Association is not only to promote interest in the use of photography in all branches of science, technology, and medicine, but also to assist its members in applying photographic methods to the solution of particular problems.

The Association proposes to establish what might be termed an Information Bureau containing, as far as possible, full particulars of the activities of all members and, in suitable cases, the existence and whereabouts of specialized photographic apparatus and equipment. These data will be used by the Association for the benefit of members as a "pool" from which information may be drawn on the very varied applications of photography to research, industry, and teaching.

Use will also be made of this information to enable personal contacts to be made between members working in similar fields and also to facilitate visits by members who may be using similar photographic procedures, to the laboratories of other members.

The field covered by the Association will be a very wide one, and will include photographic processes of all kinds, such as radiography, color photography, photomicrography, and in particular, sub-standard cinematography in all its branches.

The Association will endeavor to obtain for members information on practically any photographic problem which may arise in the prosecution of scientific work.

Meetings will be arranged from time to time at which short papers will be delivered, to be followed by discussion and practical demonstrations of apparatus and methods by members. The frequency with which such meetings can be held will depend to some extent, upon wartime conditions. It is the intention of the Association to publish a Journal as soon as circumstances permit.

The Association is anxious to foster the production of sub-standard films for research and teaching purposes, and will endeavor, as far as possible, to raise the standard of the method of presentation of such films, which at the present time is low. Members will be able to obtain information on methods of production and methods of presentation of films of scientific interest.

Further activities will be undertaken by the Association according to the demand made for such services.

Announcements of meetings will be made from time to time, and any person requiring further information or particulars of membership is invited to communicate with the Organizing Secretary, R. Mc. V. Weston, whose present address is: Houndwood, Farley, Salisbury, Wilts, England.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

VOLUME XLI

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AUGUST, 1943

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RECENT DEVELOPMENTS IN SOUND-TRACKS*

E. M. HONAN** AND C. R. KEITH†

Summary.—*Photographs and dimensions are given for a number of types of sound-tracks, some of which are in general use and some being experimental types.*

The considerable number of types of sound-tracks that have come into use in the past few years make it desirable to agree upon standard dimensions and nomenclature in order to avoid confusion. Steps in this direction have been taken with the publication of "Dimensional Standards for Motion Picture Apparatus," in the JOURNAL of this Society (XXIII, Nov., 1934, p. 247) and in a Bulletin of the Research Council of the Academy of Motion Picture Arts & Sciences, "Standard Nomenclature for Release Print Sound-Tracks" (November 24, 1937). However, in the several years since the publication of these standards, the number of types of sound-tracks in common use has considerably increased. It is, therefore, the purpose of this paper to publish illustrations and brief descriptions of the most commonly used tracks and also some experimental tracks in order that suitable dimensions and nomenclature may be agreed upon and adopted as standards.

The accompanying illustrations show twenty types of sound-tracks and combinations of tracks used on 35-mm film. The illustrations are grouped according to the type of track and without regard to the relative importance or extent of use. The description of each track is intended primarily for identification since a discussion of the relative merits of the various types would require a very extensive paper. However, references are given to previous publications where more complete descriptions of the tracks may be found. All the illustrations show positive prints.

The first group of tracks shown are of 100-mil variable-density

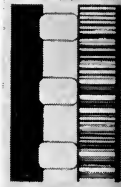
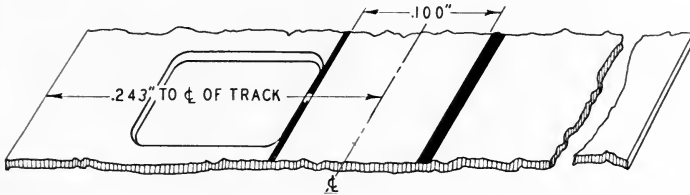
* Presented at the 1942 Fall Meeting at New York, N. Y.

** Electrical Research Products Division, Western Electric Company, Inc., Hollywood, Calif.

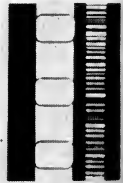
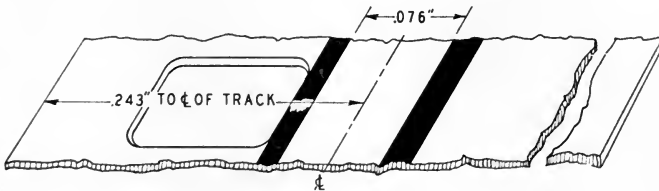
† Electrical Research Products Division, Western Electric Company, Inc., New York, N. Y.

type. It will be noted that "100 mil" and "200 mil" refer to the width of film allotted to one or more tracks. Descriptions of the "squeeze-track" and "push-pull" features will be found in the references associated with tracks of these types. The use of noise-reduction in variable-density recording may be observed on the film as an increase in average density in those portions having low modulation, although this is not apparent in the small sections shown in the accompanying illustrations.

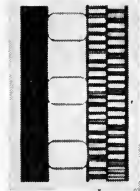
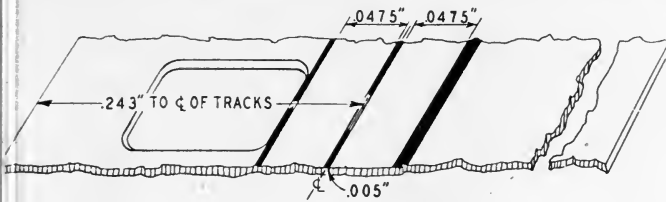
(a) *Single Variable-Density (100-Mil)*.—This is a standard release track and is the same as Fig. 1 of the Academy Bulletin.^{1, 2, 3}



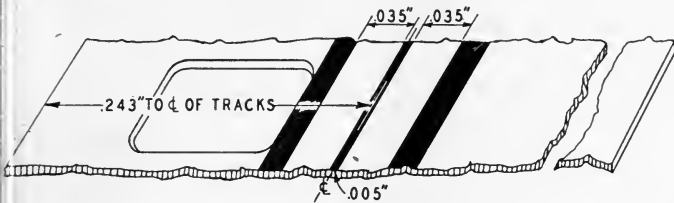
(b) *Single Variable-Density Squeeze*.—This is the same as track *a* except that the width is varied to increase the volume range. It is the same as Fig. 2 of the Academy Bulletin. The width may be varied by bringing the two outer margins closer together, as shown; by keeping the outer margins fixed and inserting a black centerline of varying width, or by a combination of the two previous methods. Since the maximum track width is 76 mils, the amount of squeeze illustrated represents a reduction of sound level of only about 3 or 4 db.^{4, 5}



(c) *Push-Pull Variable-Density*.—The two tracks are similar to *a* but are each 47.5 mils wide and 180° out of phase. This is the same as Fig. 7 of the Academy Bulletin.⁶

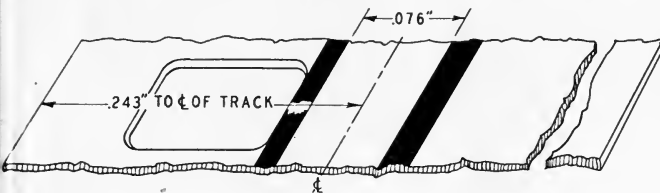


(d) *Push-Pull Variable-Density Squeeze*.—This is the application of squeeze-track methods to the push-pull track, *c*. It is the same as Fig. 8 of the Academy Bulletin.⁶

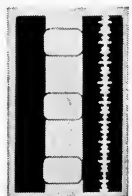
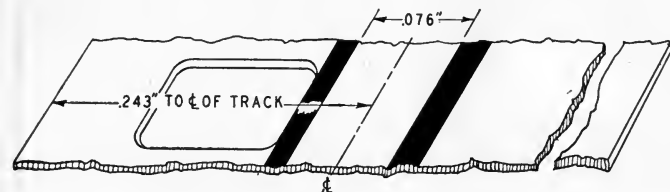


The next group are of the 100-mil variable-area type. Each is "Class A" unless otherwise noted. (See track *h*.)

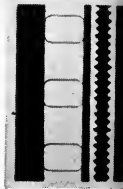
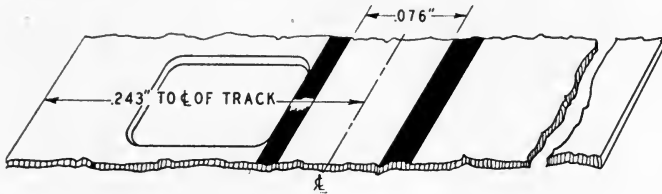
(e) *Unilateral Variable-Area*.—Noise-reduction is indicated by the change in width of the right-hand black margin. It is the same as Fig. 4 of the Academy Bulletin.^{7, 8, 9, 10, 11}



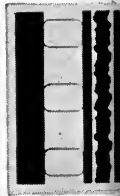
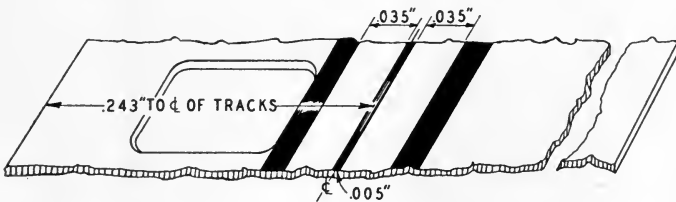
(f) *Bilateral Variable-Area*.—Noise-reduction is indicated by the change in average width of the clear center portion of the track. It is the same as Fig. 5 of the Academy Bulletin.^{11, 12}



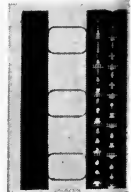
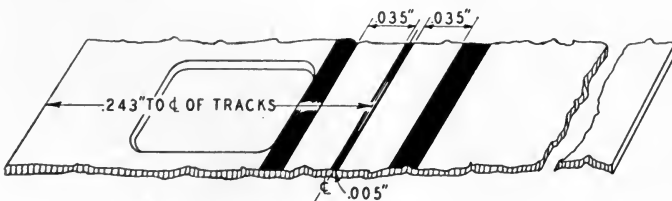
(g) *Duplex-Variable-Area*.—Noise-reduction in this case is indicated by a variation in the distance between the two black borders. It is the same as Fig. 6 of the Academy Bulletin.¹³



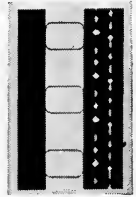
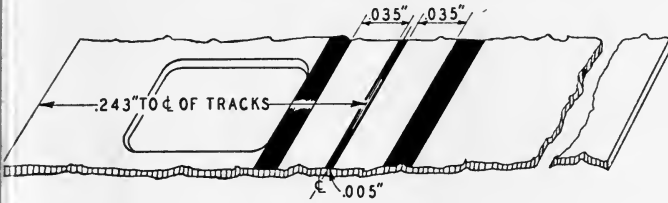
(h) *Push-Pull Variable-Area—Class A*.—The term “Class A” means that each half of the push-pull record is complete and may be separately reproduced with comparatively little distortion. In the example shown each half is a unilateral track and the out-of-phase relation is shown by the fact that a dark projection on one side is always exactly opposite a white indentation on the other side. The same effect is obtained if each half of the push-pull track is recorded as a bilateral variable-area track. Noise-reduction is indicated by a variation in the distance between the two black borders. This is the same as Fig. 9 of the Academy Bulletin.¹³



(i) *Push-Pull Variable-Area—Class B*.—In this case one-half of the push-pull record represents only the positive half of the original wave and the other the negative half, so that the two halves must be reproduced with equal amplitudes and in opposite phase in order to avoid distortion. Since the print is opaque except where modulated, the usual bias type of noise-reduction is not required. The individual tracks may be bilateral, as shown in the illustration, or they may be unilateral.^{11, 12, 13}

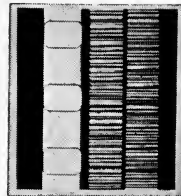
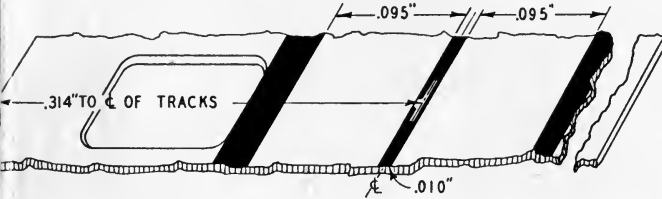


(j) *Push-Pull Variable-Area—Class A-B.*—In this type of track low modulation is recorded as Class A (each track records both halves of the original wave) but as the modulation is increased it is changed to Class B by recording the additional amplitude with the positive waves on one track and the negative waves on the other. Noise-reduction is not used in this type of sound-track.¹⁴

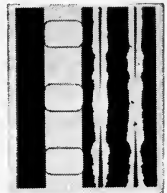
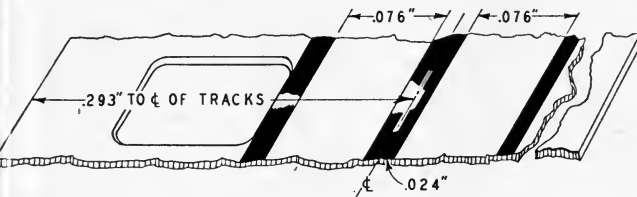


The next group of tracks occupy a width of 200 mils and are consequently not used on present standard combined sound and picture prints.

(k) *200-Mil Variable-Density.*—This is a push-pull combination of two 100-mil variable-density tracks.⁸



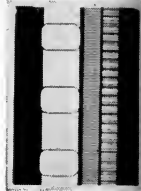
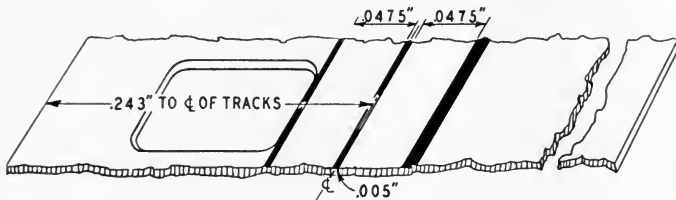
(l) *200-Mil Variable-Area Center Shutter.*—This consists of two 100-mil bilateral Class A variable-area tracks in push-pull relation. Noise-reduction is accomplished by blocking out a portion in the center of each track.¹⁵



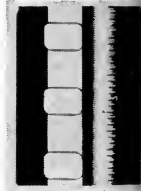
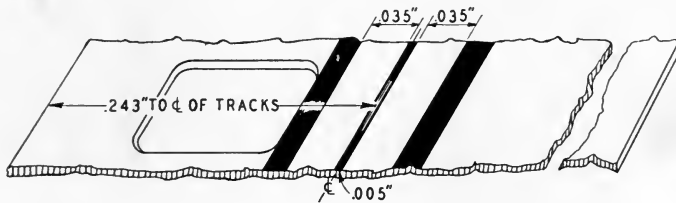
Each of the remaining combinations of tracks includes a "control-track" together with one or more sound-tracks. The control-track is generally used to vary the sound level in the reproducing system in such a manner as to increase the volume range or the signal-to-noise

ratio or both. It may be either amplitude- or frequency-modulated, and may be distinguished in the illustrations by its resemblance to a constant-frequency record. The word "complex" refers to a system in which automatic volume compression and expansion are used.

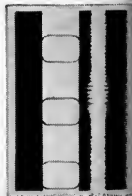
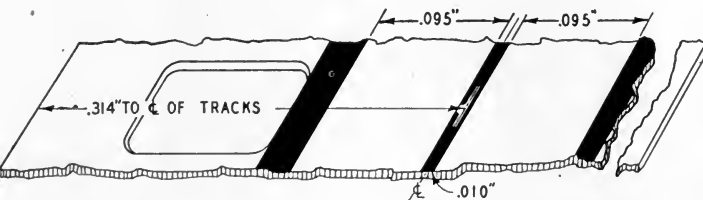
(m) *100-Mil Variable-Density Complex.*—Both sound and control-tracks are 50 mils wide and occupy the space normally used for a standard single 100-mil track. Track dimensions are the same as for track *c*.¹⁶



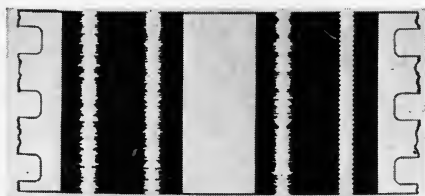
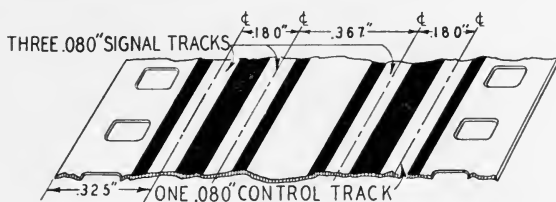
(n) *100-Mil Unilateral Variable-Area Complex.*—This is a combination of two half-width variable-area tracks which may be scanned by the same equipment as is used for track *m*.¹⁶



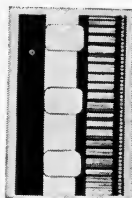
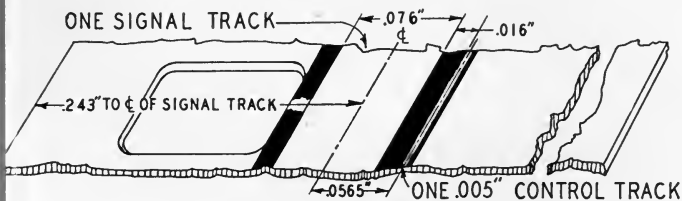
(o) *200-Mil Bilateral Variable-Area Complex.*—This track is intended for the same type of sound system as tracks *m* and *n* but utilizes a width of 200 mils.¹⁶



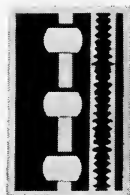
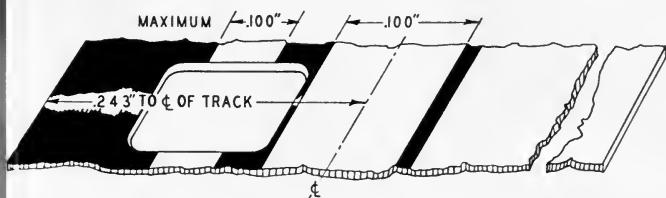
(p) *Three-Channel Stereophonic Complex.*—This arrangement consists of three 100-mil bilateral variable-area sound-tracks, one for each of three stereophonic channels, and a fourth 100-mil bilateral variable-area track on which are recorded the compression and expansion controls for all three channels.^{16, 17, 18}



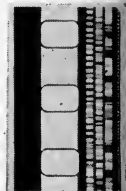
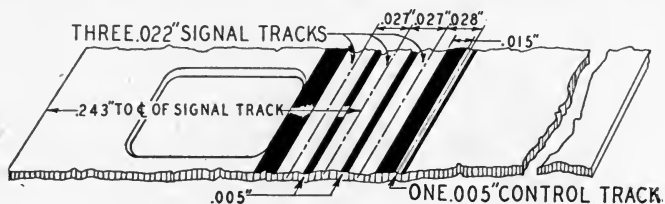
(q) 100-Mil Variable-Density—5-Mil Control.—This consists of a single variable-density track having the dimensions of a standard 100-mil release-print track, with the addition of a 5-mil-wide control-track located in the black region between sound-track and picture. In practice the control-track is variable-density, frequency-modulated. The control-track does not interfere with the playing of a film of this type on a reproducer not equipped for control-track reproduction.¹⁹



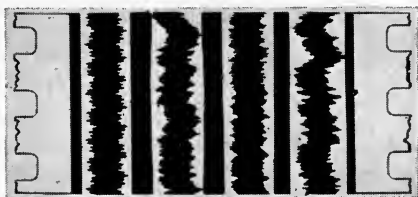
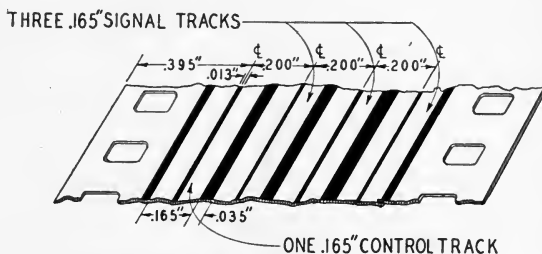
(r) 100-mil Variable-Area—Sprocket-Hole Control-Track.—This consists of a standard 100-mil variable-area track plus a variable-area control-track approximately 100 mils wide located in the sprocket-hole area. The width of the control-track determines the volume change and may also be used for switching loud speakers.²⁰



(s) *Three-Channel Stereophonic Control-Track*.—In this case three 22-mil stereophonic sound-tracks occupy the space normally required for a single 100-mil track. A 5-mil control-track in the same position as in track *q* records control signals for each of the three sound-tracks. The sound-tracks and control-track are all variable-density, the control-track being frequency-modulated.¹⁹



(t) *Three-channel—“Fantasound.”*—This arrangement employs four 200-mil variable-area push-pull tracks, three being used for sound while the fourth carries signals for controlling the sound volume in various loud speakers.²¹



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OPERATIONS OF ARMY AIR FORCE COMBAT CAMERA UNITS IN THE THEATERS OF WAR*

RALPH JESTER**

Summary.—*The Purpose of Army Air Forces Combat Camera Units is to supply tactical and operational information in the form of motion picture reports from the combat zones. This is a specialized activity and requires specialized training and organization.*

The paper describes the course of training for the units and some of the problems encountered in the field.

In November of 1942, less than six months ago, the Army Air Forces sent out to the theaters of war the first of its Combat Camera Units. These units had been activated in what was then called the Directorate of Photography, Maps and Charts, under Colonel Minton W. Kaye, to fulfill the need for specialized coverage of the activities and operations of the Army Air Forces overseas.

The purpose of these units is to supply tactical and operational information in the form of motion picture reports from the combat zones. They are instructed to photograph the conditions under which the Air Forces are operating throughout the world, to cover combat operations both on the ground and in the air, to secure photographic and recorded statistical information from pilots and crew members returning from combat and reconnaissance missions, record photographically the handling of casualties, battle damage, new and unusual methods of solving maintenance or mechanical problems in the field, to report photographically on the development of bombing patterns and on the altitude and intensity of anti-aircraft fire over specific enemy positions.

* Presented at the 1943 Spring Meeting at New York, N. Y.

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The assignment is pretty broad and consequently the ideal combat cameraman must function with the dependable efficiency of a trained motion picture technician, coupled with the unscrupulous inquisitiveness and obnoxious tenacity of the newsreel man. That this latter quality is certain to be found in one spot at least is evidenced by the fact that a general recently returned has reported that, "That damned cameraman is getting in everybody's hair—but I'm for him!"

This presents one of the key problems of the photographic coverage of modern war—how these highly specialized technicians can operate among highly specialized technicians of another sort and what supplementary military training enables them to do so.

From the beginning of the war, the Germans had already realized the value of the motion picture camera in a conflict of global proportions. They saw that pictures could bring the field of battle within view of all, from the general staff to the lowest trainees, as well as within view of the people at home. And, moreover, the pageant of victory could be brought to the people who were to be intimidated by documentary evidence of German prowess. To whatever uses the German Army may be putting motion pictures now, the organization for it was developed and put into operation as far ahead of us as was the rest of their war machine.

The American military mind, with some notable exceptions, was not as quick to grasp the potential of this medium for reporting infinitely varied operations on an intercontinental scale. Moreover, covering the operations of such a thing as an Air Force presented special problems which, incidentally, are only now beginning to be mastered.

Such mastery is necessarily based upon the development and careful integration of personnel and equipment, together with transportation, processing, and dissemination.

From the standpoint of personnel, the Air Forces leaned toward the policy that the making of motion pictures is a highly specialized activity and is best conducted by individuals who are experienced in its processes. Consequently, men were sought within the industry, with emphasis upon actual production experience in the newsreel, entertainment, or industrial field. The chief of the Motion Picture Branch, Technical Service Division, AAF, was brought from the ranks of well known directors; he is Lt. Colonel William J. Keighley.

The course of training for Combat Camera Crews before going

overseas is tough and thorough. Due to the fact that these men operate under combat conditions and form part of the regular bomber crews over enemy positions, it was necessary to decide upon the advisability of making a machine-gunner out of a cameraman or a cameraman out of a machine-gunner. It was concluded that a cameraman is the end product of a great deal of experience, and can not be turned out in a few weeks.

Consequently the entire complement of each unit undergoes a complete course of military training which includes, among many other things, flexible gunnery. As you may know, the Air Forces training program lays particular stress upon the fact that a bomber crew is a *team*. To inject into this closely knit group a man who is along for the ride—"to snap pictures," as the other members might think of it—would be unwise. It is letting you in on no secret problem of morale to point out that in some areas this was at one time a factor. However, if the pilot and his crew feel that the cameraman is capable of holding up his end, and that he has been trained to know what to do under fire and can drop his camera for a gun, he becomes one of the crew—each respecting the other for his specialized contribution. Once in the air they all share the same risks.

In this connection, reports have come from the front that three cameramen have been officially credited with enemy planes. Most recently, Tech. Sergeant James Bray replaced a wounded gunner and shot down an *ME-109*. Lt. Mogen, cameraman, was less fortunate—he failed to return from Attu.

Each unit includes several cameramen, a sound crew, still photographers, drivers, an adjutant, *et al.*, in sufficient numbers to allow detachments to cover different areas and missions simultaneously. The impression should not be had that all the enlisted men are from Hollywood or the newsreel field. This is more nearly true of the officer personnel, whereas the majority of the enlisted men are from the field of commercial photography or have been graduated from the Army Air Forces Photographic School at Lowry Field, Colorado.

Nor is every man in the unit on flying status. Only those whose duties require them to engage in regular flights for photographic purposes and have passed the proper physical examination are classified as air crew members, along with the radio men, gunners, and engineering crew. Such men wear the crew member wing insignia if they have had fifty hours of flying duty as a member of an aircrew, or have participated as a member of an air crew in an opera-

tional combat mission during which exposure to enemy fire was probable and expected, or have been physically incapacitated for further duty as a member of an air crew while a member of such a crew because he was wounded as a result of enemy action or injured while discharging the duties of an air crew member.

Motion picture photography from an airplane presents many and special difficulties that have long challenged cameramen, engineers, and designers of equipment. Photographing another airplane or group of planes or a ground objective from another swift-moving plane is a difficult job with complex problems involving such factors as vibration, the slip-stream, obstructions to vision, and temperature. This is further complicated by the fact that the plane is primarily a military weapon and the film, except for reconnaissance, can not strictly be considered such. The cameraman does not shoot to kill; he shoots to preserve. As a result, his position in the plane receives a priority after that of the gunner, who must have the greatest range of vision for the field he is to cover. Various ingenious approaches have been made to this problem, even to cutting a window in the leading edge of the vertical stabilizer supporting the rudder. Mounts have been developed to photograph through the floor and all other available openings that will not conflict with the functions of the aircraft; in some instances the cameras are motor-driven and remotely controlled by a member of the crew. Shooting through the plexiglass of the nose is good for certain types of planes and subject matter, with or without a fixed mount. Hand-held cameras are, of course, most flexible; but produce pretty jumpy results in atmospheric turbulence or where bumpiness is produced by anti-aircraft fire.

The units have been provided with the best equipment available; but in the early stages, at least, this did not always mean a great deal, because little or nothing was available. Of necessity the equipment is heterogeneous.

I am not at liberty to tell you the exact numbers of either men or cameras; but there is, roughly, a camera for each man in the unit. Single-system sound cameras are provided each unit—Audio Akeleys, Wahls, or Mitchells. Each has several silent motion picture cameras, either Bell & Howell or Akeley, and several motor-driven Eyemos with 400-ft magazines. The most numerous types are the hand-held cameras—Eyemo, Cineflex, DeVry, Filmo, and Victor. For still cameras there are two speed Graphics.

As mentioned above, one of the photographic objectives of bombing missions is to provide a film report on the development of bombing patterns, and to record the altitude and density of flak. In some areas this is done at extremely high altitudes, with resultant complications due to low temperatures. Men have risked their lives in the performance of a job at which they were licked before they started. One of our men was downed in Crete, later crash-landed in the Mediterranean and lost his camera, finally got over Naples, at last had a shot at his objective, and had his camera freeze.

As a result of such discouragements, the building of a special camera was undertaken, a camera that would not be affected by the extremes of temperature encountered in the shooting of motion pictures from planes. Tests on one camera being built for the Air Force to meet these extremes have proved that this is possible, and it has functioned perfectly at 65 degrees below zero.

On this planet, at least, it is impossible to expose film under more varied light and atmospheric conditions than are being encountered by our combat camera units. From Persia to Guadalcanal, from the Aleutians to Burma, men are filming Air Force operations under an infinite variety of handicaps. One crew reports twelve consecutive missions over Kiska, with increasing Japanese anti-aircraft fire, and never a hole through the mist to get a shot. Others are nursing rawstock through the tropical moisture of New Guinea and watching for Jap snipers.

If it is your custom, out of courtesy, to accord these papers some measure of applause, may I be allowed to endorse mine over to the men of the combat camera crews throughout the world who are faced with as tough a photographic assignment as has ever had to be put on film.

DEVELOPMENTS IN THE USE OF MOTION PICTURES BY THE NAVY*

WILLIAM EXTON, JR.**

Summary.—*Naval training films are based upon a complete and continuous integration of requirements, planning, production, and utilization. This is in order to provide maximum effectiveness for audio-visual aids. The conditions of final utilization tend to govern the treatment, the reducing or eliminating the need for any superfluous content.*

Since my last address to this Society, the Navy's use of motion picture films has been developing extensively and by geometric progression. Those of you who are in the business of manufacturing and distributing 16-mm motion picture projector equipment may have some inkling of the incredibly large number of projectors we are attempting to acquire.

Those of you who are connected with certain motion picture producing organizations will have some conception of the vast range in the number of productions which we are initiating. Those of you who are connected with the provision of film stock and with developing and printing laboratories will have an idea of the enormous amount of footage we consume. I am not permitted to give you exact figures in any of these categories, but I believe it is fair to state that the actual figures would probably seem surprisingly high.

The daily mails bring in numerous requests for films. Every day we receive dozens of requests for specific titles. Some of the individual requests list hundreds of titles. The Navy's motion picture film catalogue, which is not available to the public, is half an inch thick and contains several thousand items of film and film-strip. The Navy makes use of films from many sources. Some we derive from our Allies, some from commercial sources, and others from the Army and Coast Guard. The Marine Corps produces films, some of which are valuable for other Naval purposes. Our major source, however, is production for and by the Navy itself.

* Presented at the 1943 Spring Meeting at New York, N. Y.

** Lt. Commander, U.S.N.R., Bureau of Navigation, Navy Dept., Washington, D. C.

As a general rule film production in the Navy originates with a request from a Naval activity; this activity may be one of the Bureaus of the Navy Department, it may be the Commandant of a district, or it may be the Commanding Officer of a training activity. Such a request for production is normally addressed to the Bureau of Aeronautics *via* the Bureau of Naval Personnel. It therefore reaches the Bureau of Naval Personnel first; and is there subjected to rather careful scrutiny. A survey is conducted to determine all comparable parallel or related material, in order that duplication may be avoided and in order that a knowledge may be had of everything of the kind requested that may already be in existence. It is then scrutinized from the point of view of utilization; that is to say, the request is considered with expert knowledge of the places where the subject is taught, the conditions under which it is taught, the numbers of men, and the sizes of the groups to which it is to be taught. Also considered would be the relationship to other things that have been or are to be taught to the same men, and any other matters that affect the eventual utilization of the finished film. Naval and training policy and doctrine are considered, and a priority is assigned to the film indicating its relative importance. Any other suggestions that may seem germane are added, and all this is incorporated in an endorsement accompanying the request to the Bureau of Aeronautics.

The Bureau of Naval Personnel may also conduct an extensive inquiry into the needs for the film, the concept behind it, the extensive character of the film required; whether the training need could be served as well by film-strips or even by non-photographic training aids, such as wall charts or models. Provision is made for the designation of a technical advisor who will provide official guidance in the Naval aspects of the film. This endorsement accompanying the request reaches the Bureau of Aeronautics, where the Training Film Unit then takes the matter up. This unit of the Bureau of Aeronautics is charged with arrangements for actual production, which involves the selection of a commercial producer or arrangements with the Photo Science Laboratory. The project supervisor and an educational consultant are assigned, and these confer with the technical advisor. The production is then under way.

In many cases, the film in its preliminary stages is referred back to the Bureau that requested it; in some cases in the form of a script, and in other cases in the form of an uncut print in the preliminary

stages before the sound-track is added. Usually, the technical advisor is present at such a preliminary showing, and final suggestions may be made before the production is entirely complete. Experience has shown this sort of final review to be very desirable in many cases. This is especially so in training films that apply to subjects of wide, general application; and which are not highly technical, and therefore of limited audiences.

Two of the newest developments in the Navy's use of training films are involved in the post-production stage. They have to do with the Navy's present practices in connection with distribution and utilization. The present distribution procedure is to set up allowance lists of training film for each naval activity; that is to say, a list of the individual titles that each activity should have for permanent possession, as being particularly appropriate to it. In addition, a number of training-film libraries are being established in strategic places. Each of these libraries is thoroughly equipped with films and also with extra projectors and equipment, and facilities for projector repair and film renovation. Through these film libraries, films are available for loan to naval activities everywhere upon request.

Some fifty highly qualified educators, with special experience in the field of using audio-visual training materials, have been commissioned and are being stationed in training activities where their advice and guidance in the use of training films and other training aids are now resulting in the derivation of maximum benefit from the availability of this material.

In attempting to be brief, I have, of course, eliminated many details that are important and interesting. It is a fact, nevertheless, that the Navy's use of motion picture films today is absolutely complete and continuous from the original request through planning and production to the distribution and the utilization of the film. All these and every step in each one of these stages are a part of a continuously planned and integrated program guaranteeing maximum effectiveness and usefulness of each film. It is not pretended that every step in the development and use of each film is a perfect one; nevertheless it is believed that this comprehensive program enables the Navy to derive benefits from the use of films in training that are not otherwise available. It is believed that the Navy's experience in the development of this procedure will be of great value to the future of educational films.

One tendency inherent in this situation is to get still further away from the so-called "Hollywood" or "entertainment" technique in educational or training films. A film is not required to sell itself by attempting to be witty or amusing. The film is tied into a training program of which it is a logical and important part. The value derived from the film, therefore, can be any fraction of the value that has been put into the film, depending upon the skill with which the educational program is conducted. Comparatively few films now being produced by the Navy department rely upon interest-arousing or interest-exciting superfluosity. On the other hand, the films are not shown indiscriminately, and therefore the audiences seeing them know that there is a purpose in seeing them. They are properly prepared for seeing these films, and the whole situation surrounding the showing of the film is such as to arouse in them a recognition of the necessity for deriving from the film all that is possible.

An example of this is the Night Lookout Training Program. The Navy has erected a number of Night Lookout Training Centers provided with stages simulating night conditions and equipped with ship models of various types; and with lighting systems permitting the simulation of dawn, dusk, distant gun fire, and so forth. A competent lecturer utilizes this equipment to demonstrate the principles of being a good lookout at night and of using the eyes properly at night. In this connection night or dark adaptation and the physiology of the eye become matters of great interest. A film that has been produced for the Navy, and which illustrates the physiology of night vision is shown in order to assist in understanding this subject. The film is technical and contains no entertainment matter whatever; and yet under the conditions in which it is shown, it is regarded as extremely successful in producing the desired effect by delivering the desired information.

Many of the simpler aspects of utilization require attention that is not often given them. Such simple and obvious matters as proper projection and proper seating in relation to the screen, so that minimum satisfactory vision is obtained, are matters that may require guidance. The fact that the average man can not continue to derive benefit from seeing instructional film for a prolonged period is a fact that needs to be driven home. Our utilization experts insist that not more than ten to fifteen minutes of instructional film be shown at any one time, and this should generally be preceded by introductory

remarks and be followed by remarks from the instructor that will tend to drive home what should have been learned from the film.

Other functions of the utilization officer include advising those conducting training activities as to the kinds of film and other materials that are available for their special purposes. This involves far more extensive activity than can readily be imagined by anyone who is not familiar with the vast range of naval training activities, including at present many hundreds of different establishments.

If any of you could sit at certain desks at the Navy department, and hear the telephone ring, and answer telephone calls from high ranking officers attached to important ships of war, demanding projectors and films for those ships on an urgent basis, you would realize that the fighting Navy is convinced of the value of training films. That value, to the Navy, is increasingly based upon an intelligent and comprehensive conception of the kinds of film desired, their application to the subject, and the conditions and circumstances under which the subject will be taught.

PROBLEMS IN THE PRODUCTION OF U. S. NAVY TRAINING FILMS*

ORVILLE GOLDNER**

Summary.—The organization of the Training Film Branch and the scope of its job are indicated. Problems encountered in the production of the Navy's training films are considered. Special emphasis is given to research, pre-planning of production and script writing. The difficulties that result from undertaking an extensive training-film production program under wartime conditions are presented briefly.

Slide-films and motion pictures for the Navy are being produced under the supervision of the Chief of the Bureau of Aeronautics, who was directed by the Secretary of the Navy, in August, 1941, to ". . . fulfill the photographic requirements of education and training in the naval service." The Photographic Board, which made the original recommendation on which the Secretary acted, lumped the responsibility for the photographic requirements of education and training with other photographic responsibilities and assigned them all to the Bureau of Aeronautics because of its long-time experience in naval photography.

As a result of this directive, the Photographic Division of the Bureau of Aeronautics, through its Training Film Branch, serves the entire Navy in its film production program. Requests for film productions originate from training officers in the various naval training centers maintained throughout the country, or from officers in the training divisions in Washington. Requests come to the Bureau of Aeronautics *via* the Bureau of Naval Personnel, which has responsibility for all naval training. There are, however, two exceptions to this. They are the requests that originate in aeronautical activities and those that originate in the Secretary's office. These requests come to the Chief of the Bureau of Aeronautics and are forwarded to the Training Film Branch *via* the Director of Photography.

* Presented at the 1943 Spring Meeting at New York, N. Y.

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When production requests are approved by the cognizant authorities, the Training Film Branch assigns a two-man team to work with the technical advisor in outlining and producing a training film on the subject. One team member is the educational consultant, the other the project supervisor. Essentially, the project supervisor is the coördinator and administrator of the project for the Navy. Besides contributing the film "know how," he activates the project through his liaison relationships with the several persons jointly engaged in it—the technical advisor, the Navy or commercial producer, the educational consultant, the procurement and cataloguing departments of the Training Film Branch.

The educational consultant helps to insure that a film, as planned, teaches. He not only defines a film's purpose but helps to plan it according to well established pedagogical principles. He finds ways to fit it into existing curricula and may assist in adapting existing curricula to the new instructional program. In several instances it has been found that pictures have forced realignment of existing curricula.

Since the organization of the Branch charged with responsibility for producing films for the Navy (July, 1941), the total number of projects completed is 1692. Of these, 1412 were slide-films and 280 were motion pictures. The total number of projects in production at this time is 1296, of which 850 are slide-films and 446 are motion pictures. Requests for production of films on additional subjects of interest to Navy training are coming in at the rate of 200 a month—clear evidence of the Navy's interest in the medium.

Another line of evidence showing the Navy's dependence upon training films is found in the film distribution figures. In the last quarter, over 90,000 prints have been distributed. Nearly one thousand individual activities have been served. These include both ships and the nearly five hundred schools and naval training establishments ashore where men are trained before being assigned to the fleet or to which they are returned for further training after some fleet experience.

The training films the Navy makes and uses have been designed to be used in classrooms at the time in the course when they will help the instructor to standardize operations and make ideas clear to his students. They are not made to be shown as separate, uncorrelated features. And when planned for one specific group, as is most often the case, they are not expected to meet the complete needs of another

group being taught things in a different way. For example, slide-films designed for use in the Aviation Service Schools for training enlisted men in maintenance and repair of airplanes have not been found particularly helpful for training civilian personnel in the Aviation Assembly and Repair Shops, even though both groups are working on the same model of airplane. The films the latter need are definitely job-analysis films on assembly and sub-assembly of parts, much too detailed to be of use in the Service Schools. The purposes served in each are different, and hence the training aids must of necessity be different too.*

It is our task continuously to analyze the problems peculiar to and characteristic of every training situation. Training films must fit. Simply, they must assist in training or they are an expensive waste of time and strategic material.

We find it necessary to repeat frequently that we are not in the business of making films *per se*; we are in the business of making training aids. That is why in a training film program like the Navy's there is no place for the movie making *prima donna*. Celluloid fever is easy to get, but the making of effective training materials requires analytical, straight-line thinking, planning, and execution.

When an official request reaches the Training Film Section, there are still a great many questions that have to be answered before a producer can be assigned to the task of producing the training film. A thorough job of research and pre-planning must be done. Due to the problems inherent in a training program during a war period, basic research and pre-planning take on various aspects. First, there is the research based upon standardized doctrine, good or bad, realistic or unrealistic, which has been used over a long period of time by a fairly well stabilized training activity. Second, there is the research on a training program where there is no established doctrine — where the whole training program is so new that a syllabus or simple outline has not been developed.

Frequently it becomes the job of the Training Film Branch to establish the doctrine along with the production of the training film. In many cases, a training activity without established doctrine permits the creation of a more effective training film than the activity

* The foregoing was written by Lt. Reginald Bell, U.S.N.R., Senior Educational Officer for the Training Film Branch. It is reproduced here substantially as it appeared in *Visual Review* for 1943. The remainder of the paper was written by Lt. Orville Goldner, U.S.N.R., Officer in Charge, Training Film Branch.

that presumably has all its information frozen in outmoded handbooks and syllabi. It is far more stimulating for the project supervisor, the educational consultant, and the technical adviser to approach a problem that has not been thoroughly explored. A training film that evolves out of such a situation is almost certain to be more operational and less abstract than one that has been built out of a maze of words and formulas.

If no technical adviser is indicated on a request when it arrives at the Training Film Branch, it is obvious that the Branch must insist upon the appointment of a technical adviser before the basic research on the training film project can begin. It is always hoped that the technical adviser will come to the Training Film Branch with two basic qualifications—first, that he will be a subject-matter specialist, thoroughly experienced in the technical aspects of the proposed training film; second, that he have sufficient authority to make decisions that will hold and be approved by his bureau or the activity which he represents. If the technical adviser happens to be a desk engineer with years of experience or a technical writer who has thought in terms of words and mathematics entirely when considering his subject, he almost invariably creates many difficulties for all those concerned in the production of the training film.

Let us consider for a moment the first type of research—that based almost exclusively upon doctrine set forth in great detail in handbooks and manuals. If the subject happens to be mechanics or electricity or any one of a hundred other involved subjects on the complicated apparatus of this war, in all probability, the authors of the manuals and handbooks were engineers sitting at the desks of the manufacturer of the equipment involved. It has been the practice of the armed services for many years to buy with their equipment instructional manuals that are supposed to contain the sum and substance of all the problems involved in the construction, installation, maintenance, and repair of the equipment. Frequently these have been considered all that is necessary for the guidance and training of competent personnel. Needless to say, these handbooks and manuals are generally one-sided—they tell the story about the equipment that the manufacturer wants to tell. Constructed as they are, in Detroit, Chicago, Cleveland, or other industrial centers, miles from the field of operation in which the equipment is used, they are unrealistic, verbose, and crammed with mathematics that only thoroughly experienced engineers can understand. And yet more

than once, these engine encyclopedia, Diesel dictionaries, and radio rhetorics have been given to training film officers as scenarios. "Certainly," says the technical adviser, "what more do you want?" "Just make pictures to fit, and you'll have a beautiful training film." And, believe it or not, we've made a few along this line—abstract talking panoramas to delight the eyes and ears of our best engine Einsteins.

We have been speaking here of one kind of material that is presented as doctrine for the construction of training films. This is the overcomplicated and unrealistic which makes picture planning difficult. Another kind of material presented as doctrine is the oversimplified—that kind that grew up in an unstudied training program, in the hands of an alleged instructor who thought that generalizations were enough. This kind of material contains profound statements such as "Proceed to the engine, make adjustments preparatory to starting, turn up fuel oil to the proper level, turn throttle to recommended starting position, proceed as recommended in Section C, p. 32 of the Manufacturer's manual, serial number 836, *etc., etc.*"

We who are involved in the construction of training aids for the Navy know that neither of these kinds of material is sufficient as a basis or plan for an effective training film. Our job of basic research must go further. Consider for a moment the construction of training films on a series of large tactical problems which change from day to day just as the war itself changes from day to day. The movement, the pattern of strategy, the war equipment that won a battle yesterday may not win the battle at some future date for which we are building, and yet, we have to make training films on these problems too. One such problem has kept us involved for over a year. In that time, tactics have changed, equipment has changed, and personnel has changed. Technical advisers who were considered authorities when we began may no longer be considered authorities, or they have been removed to fields of operation inaccessible to the Training Film Branch, for every day, more men must go to combat areas whether they are working on training films or not. It is safe to say that within the year, typewritten material a foot thick has been accumulated on this particular problem. Dozens of experts have been consulted and countless maneuvers have been watched for the purpose of accumulating authentic, operational data. There must be continuous checking and cross-checking—for an error, made

real and in effect true by projection on the screen of the classroom, could conceivably lose a battle if enough people believed it and acted accordingly. Conversely, the truth projected and made real—simply and operationally—might *win* the battle. It is this admitted effectiveness that justifies the production of training films; in fact, demands it.

Such a job of research and analysis is not an easy task. It is difficult enough to get a consensus on problems where standard mechanisms are involved. It is overwhelmingly difficult to get a consensus when broad tactical problems and intricate new machines of war are involved. Often, much valuable time is lost in getting a decision on a simple point, and these delays are not easy to overcome or explain; for in the end, there is the project file in the Training Film Branch which indicates that a certain training film has been in production an inordinately long period of time. With a few projects like this, the total production program is bound to look out of joint. But the research, pre-planning, checking, and cross-checking must be done.

The second research technique—that which is without benefit of doctrine to begin with—is largely observational. The project supervisor, educational consultant, and technical adviser travel to the training activity that is to furnish the problem and the pattern for the training film. A typical example would be the assembly of a pontoon bridge. Let us assume that this is a new activity for the Navy, that the pontoons are new, that the total job is a part of an entirely new operation which extends the function of an established Navy rating. On such a problem, the researchers scrutinize what is going on. This may take a couple of days or a couple of weeks or longer. It may mean a trip to the South Pacific or the Caribbean, to one location or many locations. But inevitably, it means a detailed analysis of work under many conditions. With the training officer in charge, project personnel attempt to determine what tools are best and what techniques are best for the job to be done, wherever and however it must be done. The training film must, of necessity, set high standards for this particular operation wherever it is shown. Perhaps the training officer had never thought of his job in terms of the best tools and best techniques; perhaps it had been done previously with whatever tools were at hand by whatever method seemed most appropriate at the moment. Obviously, this is not precise enough for the discerning eye of the camera. When a simple

wrench in use is projected on the screen, it may appear at once to be either too large or too small, or badly handled. Unskilled and indecisive workmanship and inappropriate equipment becomes readily apparent when reviewed on the single plane of the classroom screen. A recent example of this happened in a series of films being undertaken by the Branch on the disassembly of a certain engine. The two Machinist's Mates assigned to appear in the films were thought to be thoroughly qualified for the job. Aboard ship in the engine room, they could undoubtedly get by as able mechanics. And yet, when the first sequences of the particular training film were projected, it became apparent immediately that these two men were inept with tools and frequently used methods that could not be considered as standards for the training film. The sequences were re-shot and the films continued with more experienced mechanics who knew the proper tools and techniques. All this points to the fact that research and pre-planning can not be casual if effective training aids are to result, and further that the production of training aids must not be considered as a manufacturing process in which one film formula is the skeleton over which a wide variety of subject matter can be stretched. Whenever this happens, the formula becomes more important in a teaching situation than the subject matter it purports to present. Training films designed on this pattern are inevitably soporific and can not help but defeat the purpose for which they are intended.

What does the Training Film Branch do after the research and pre-planning on a given project are considered finished and approved to a point where production may be started with safety? A qualified producer must be selected. Scripts must be written; a location or locations must be prepared. Personnel and material must be allocated. These and a myriad of other jobs are next in line.

And all this must be accomplished in some order while the Navy and the nation are at war. All this must be done without stopping the flow of men and equipment to the battle front, without taking too much of the valuable time of technical advisers who are at the same time preparing themselves and others for actual contact with the enemy. All this, like research, is not easy. Every step of the way is fraught with problems. There is always the problem of priority. Who shall be first and what project? When everything is needed now and urgency is the order of the day, there still must be some plan—something first and something second—when the time of

leaders and the allocation of facilities are considered. Then there is the problem of security. The Navy's equipment and plans have to be protected vigilantly day and night, for the enemy is ever present and alert. How is it done? Many of you are producers working for the Navy and you know. It is sufficient to say that it is done, slowly, continuously, meticulously. It is tedious and time-consuming for you and for us, but when the safety of the nation is at stake, it is only wisdom to be hyper-cautious.

Let us examine critically some of the steps in actual production. What of script writing? It should not be necessary to labor the point that a training film is not like a theatrical film and not for the same purpose, and not for an audience with the same mental set. Neither is a training film like a newsreel which cuts quickly from subject to subject accompanied by a commentary which on analysis says nothing but says it well and with so much seeming authority. Each type of film has its place in our culture, but one can not be substituted for the other in a training situation. Yet, many of the writers of the Navy's training films are hard to convince of this fact.

The writing of a script for an effective training film requires first of all the ability to penetrate the obvious and the loosely accepted truths in a given situation. It requires persistence and a prying curiosity. It requires incisiveness and straight-line thinking, and with it all, the ability to put it on paper in acceptable English with an economy of words. The writer of a training film script must, of necessity, have a vivid imagination. He must be picture-minded first and word-minded second. In analyzing his subject matter, he must ask himself constantly, "What is the picture at this point that will tell the story in terms of the objective?" And, having determined the picture, he must then ask, "What is the simplest meaningful statement that I can make that will extend the effectiveness of the picture and add to its retention potentiality?" The writer with genuine ability for training film production understands that he is working with a medium in which the primary value is visual and the secondary value is auditory. He knows that he is not writing lectures with pictures "to fit"; he is organizing pertinent pictures of subject matter in movement, using the fewest possible words to describe, to emphasize, to extend.

Does the Training Film Branch get what it wants in the way of scripts for its films? Frequently it does, but time after time it does not. There is much revising, much compromising, and occasionally

the accepting of the obviously bad in the name of urgency. Generally, no one can be blamed for the inadequacies. Perhaps, in spite of all research, sufficient data were not available to give continuity to the picture plan. Perhaps certain pictures were known to be unobtainable and without them the plan would have blind spots. Then again, perhaps, there had been insufficient experience with a given piece of equipment to furnish the facts about a certain operation.

However, there are times when script shortcomings stand out as direct evidence of the writer's refusal to accept the training film as a special instrument with a special purpose. When writers insist upon using pictorial *cliches* at the beginnings and ends of all training films, it becomes obvious that they do not know how to begin and how to end the film in terms of the objective originally set forth. It points to a limited concept of the job to be done and a definite lack of ability to work in the film medium. Words can not describe the fatigue that comes from going to the projection room and seeing film after film begin and end with the opticals made up of the same twenty-five best stock shots of ships plowing through the waves, big guns shooting at nothing, and planes peeling off, accompanied by ominous words in sepulchral tones on the scope of the war and the size of the job and the beauties of Democracy and the beating we are going to give Hirohito, *etc., etc.* And we must not forget, indeed, can not forget, the overloud, strident music that fits the film the way ice cream goes with dill pickles.

The writer may not wish to take credit for all this, but he sets the pattern—good or bad—and the director, the cameraman, the editor, cutter, and narrator all follow the line.

Photography itself is probably the least of our problems. Most cameramen are able to get some kind of image on the film. Inasmuch as a large part of the shooting of training films must go on in spite of weather conditions and countless other limitations, it is generally necessary to accept photography that is adequate, rather than good. To insist upon photography that is the best possible under ideal conditions in a given situation would often delay projects beyond reasonable limits.

Producers who work on training films for the Navy are always conscious of the demands for close-ups, for better definition, and maximum depth of field. These are essential in operational training films. Of great importance also are the orientation and re-orientation shots

for which the Training Film Branch asks over and over again. A training film that skips around over an engine or a ship or anything else with close-ups and medium close-ups is certain to lose and confuse the trainee. He must be orientated to the problem in the beginning, and must be re-orientated at intervals throughout the film. This orientation must be operational; that is, it must be from a position in which the trainee would find himself if he were working with the real thing in a tactile relationship. Frequently, effective orientation shots are not possible in live photography, and it becomes necessary to resort to diagrams or other pictorial devices. Any device is legitimate if it achieves the purpose for which it is intended. Here again, like all the other complicated aspects of training film production, the photography is right when it gets to the screen the cogent picture information that the training situation demands.

It is not necessary to have beautiful clouds in all exterior shots and to have every Diesel mechanic backlighted in close-ups to make him glamorous, but realistic esthetics have a place in training films. The cameraman who understands his medium, who uses his camera creatively and not like a garden hose, can combine on the screen the document of an activity in a composition of values from white to black that adds immeasurably to the value of the film and the pleasure of the audience.

Considerable time could be spent on other subjects as they relate to the production of training films. These include music, color, animation, sound effects, narrators—their voice quality and delivery—and the subtle but emphatic values of the great range of screen devices. There are others, but they are beyond the scope of this paper.

In conclusion, it seems necessary to say a few words about the job that confronts us jointly—you, as civilian motion picture engineers, technicians, and producers, and those of us in the armed services as technicians and educators working on the production of training films.

We have a war to win. There is much to be done before we win it and bring it to a victorious climax. Every effort we make must be to that end. Each has a job to do, and ours is training men to be more effective, with less danger to themselves, in some phase of this intricate bloody struggle. One of the media we are using for this training job is the motion picture.

How can you help more?

By studying with us the bottlenecks that are keeping all of us from being as effective as we should be. There are the bottlenecks in animation, in laboratory work, and in optical work. You can help by analyzing the facilities, the equipment, and the processes involved. Certainly, there are ways to improve all three. There must be ways to turn out more of a better product, faster.

We can look at the work being accomplished for the armed services by all the facilities of the motion picture industry with considerable satisfaction. But, in terms of the job to be done, we must look to the future with an expanding concept of the function of the motion picture and a more profound understanding of its value as a training instrument.

THE 16-MM COMMERCIAL FILM LABORATORY*

WM. H. OFFENHAUSER, JR. **

Summary.—Several years ago J. A. Maurer reported¹ upon the graininess of direct 16-mm prints in comparison with reduction prints from 35-mm negatives. Somewhat earlier² he reported upon the status of direct 16-mm sound in comparison with sound optically reduced from 35-mm to 16-mm. The comparisons appeared so favorable to 16-mm that the next step was to put the procedures into commercial use. This paper describes the methods and the machinery used for the purpose.

It was necessary to standardize laboratory and film-handling; all picture printers are of the slow-speed step-contact type, all use the same type of lamp as a light-source. All sound printers are of the optical type; all use the same type of lamp and the same type of ammeter for control. No contact sound printing whatever is used, due to the very serious losses that result from such printing.

It was found that one—and only one—raw-film material should be used for each operation—the material with the best resolving power. Fortunately the material with the best resolving power has the other necessary desirable photographic characteristics. Eastman 5203 was selected as the duplicate negative material. Dupont 605 was chosen for the release print raw stock; Agfa 250 for the original sound negative material. Kodachrome was found to be the best available material for original 16-mm films, not only for color duplicates but also for black-and-white fine-grain release prints as well.

It was necessary also to standardize inspection equipment, especially sound equipment. A film-phonograph of excellent film motion with a 0.4-mil slit image, a noise-free amplifier, and a two-way loud speaker system of the horn and direct-radiator type, with a standard 400-cycle cross-over network, is used for the inspection of 16-mm sound negatives and sound prints that are used for further duplicating (for example, prints used for Kodachrome duplicating). The overall electrical characteristic of the system is similar to that of metal diaphragm systems specified in the "Revised Standard Electrical Characteristics for Two-Way Reproducing Systems in Theaters" issued in 1938 by the Academy of Motion Picture Arts & Sciences. For combined print inspection, Bell & Howell utility projectors adapted to connect into the system used for the film-phonograph were found the best commercial compromise.

Uniformity of product is readily obtained; permanent records of each piece of film processed are sufficiently complete to permit the duplication of results long after the details of a particular job are forgotten. With but one variable in each significant step of the process, errors in processing are quickly traced and corrected. Maximum

* Presented at the 1942 Fall Meeting at New York, N. Y.; received March 15, 1943.

** Precision Film Laboratories, Inc., New York, N. Y.

uniformity is achieved simultaneously with maximum output; the methods described are well suited to mass production.

In discussing the 16-mm motion picture film laboratory and its commercial operation and practices we shall ignore in this paper time-consuming and attention-diverting frills such as fades, wipes, dissolves, and whirls, and concentrate entirely upon the operation of a laboratory in relation to the thought content and purpose of the films to be produced. In war nothing can be condoned—much less encouraged—that does not directly contribute to the accomplishment of the desired purpose.

What is the primary purpose* of a 16-mm film laboratory, or for that matter, of our 16-mm industry, now that we have been engaged in war for the larger part of a year? No one who is familiar with the facts can honestly include pure and simple entertainment and blatant advertising; there is but one real objective: training and its related films dedicated to the job of making training of ever-increasing scope available to an ever-expanding group of our trained citizens, and to make our methods more effective from the standpoint of saving time and improving the quality of instruction.

At the Fall Meeting of the Society three years ago at New York, this identical statement was made in an appeal for the production of business films for internal use;³ in today's language, training films. The fundamental requirements of a good training film program now, as then, remain essentially the same as reported by the Luchaire Committee on Intellectual Coöperation of the League of Nations in 1924:

(1) Slides *and* motion pictures should be used for maximum effectiveness. As a general rule, the use of these two adjuncts is not judiciously proportioned, one often being used to the complete exclusion of the other. We can no doubt agree that the conclusion of eighteen years ago is still valid today; too many projects use but one medium to the complete exclusion of the other.

(2) All objects and scenes that the audience is intended to watch and remember in movement should be shown in movement. Still pictures representing objects and scenes that ought to be seen in movement should be banned, as giving a distorted impression of the actual facts. Our films are much improved in this regard although we still find instances where stationary objects are photographed

* This paper does not take into account the 16-mm prints of entertainment films furnished by Hollywood to the Armed Forces.

with a motion picture camera and moving objects with a still camera.

(3) The screen can not displace the personal element; it can to some extent displace printed matter, and it should, in all events, be used in combination with it. The use of the screen in conjunction with text-books and printed matter is still quite undeveloped; its effectiveness when properly used is in the top rank of communication media. "Nuts and bolts" pictures especially can take advantage of this pedagogically correct instructional technique.

(4) The screen should be used in combination with personal contact in "getting the idea across." It should be used at the location where the teacher ordinarily operates whenever it is of advantage to do so. It should be possible to repeat the picture several times if necessary; the picture should be definitely constructed in such a manner that it will bear repetition. A really well made film can be run at least five or six times before it begins to seem dull.

Training practice has shown a tendency to bring the screen to the student instead of the student to the screen. This tendency is in the proper direction and, fortunately, is steadily growing.

It is not true, however, that films are always constructed in such a manner as to bear repetition, as is particularly necessary in films for instructional purposes. Too often a large number of diverting technical effects such as fancy wipes, dissolves, and the like have been used in a single reel. Such technical effects do not cover up the glaring defects in plot, continuity, and lack of logical presentation that are also usually present. Our technical effects wherever used shall aid the story, not "steal the show."

(5) The screen can not be used in the proper manner unless there is very wide distribution of effective up-to-date apparatus so that each teacher, of even small classes, can have his own projection equipment. The simplest apparatus to handle consistent with complete technical adequacy will be best. If the screen is to do its proper work, the apparatus must quickly become a thing in daily use.

On the whole, current commercial 16-mm sound projectors (and this includes those being currently purchased by the Government in quantity under the most strict specifications), while quite satisfactory in most particulars, almost invariably have the following inadequate or poorly designed features:

(a) *The Loud Speaker*.⁴—Present flat baffle types are hopelessly inadequate for high-quality reproduction. For semipermanent installations an efficient horn-and-cone combination such as the Jensen speaker, supplied under the

Bell & Howell trade-name "Orchestricon," is quite suitable. For semiportable use, a reflex-type horn of reasonable efficiency and frequency characteristic such as the Jensen "Hypex" is quite suitable. The loud speaker should be designed to cover with sound the area to be served by picture.

(b) *Sound Optics*.—Present machines (except only the Eastman Kodak) use sound optics of inferior resolving power providing very coarse projected slit images; a width of not greater than 0.5 mil is necessary for good-quality 16-mm sound reproduction. On the best of other machines, the slit width is twice as wide as that recommended, 1.0 mil.

(c) *2-Inch Picture Projection Lenses*.⁵—About 70 to 80 per cent of the projectors in use should use a projection lens of this focal length; unfortunately all lenses of this focal length of wide aperture ($f/1.6$) made without field flatteners have very poor resolution in the corners and very bad field curvature. Only one manufacturer (Eastman Kodak) regularly supplies all 2-inch lenses with a field flattener. The field curvature and poor resolution in the corners still persist in 2-inch lenses of smaller aperture although in some cases not to as great a degree. U. S. Army and other Government specifications have sought to get around this problem by specifying lenses of 3-inch focal length which, at smaller apertures, show less field curvature. While there is an improvement in flatness, the focal length is definitely wrong for the average application as judged by the criteria of the Non-Theatrical Committee Report of July, 1941;⁶ the projected image is too small and the perspective incorrect.

(d) *No Provision for Proper Focusing of "Non-Standard" Emulsion Position Prints*.⁷—Most projectors have no provision whatever for refocusing sound optics for Kodachrome duplicates. This results in tubby, noisy, and unintelligible reproduction from even excellent films. Eastman Kodak is the only manufacturer that provides sound refocusing as standard equipment on any standard projectors; Bell & Howell provides this feature as optional equipment at extra cost. Since there is almost a 10 to 1 cost ratio between cheap black-and-white prints and good Kodachrome duplicates, it seems an anomaly to provide the better reproduction for the cheaper film. No manufacturer makes any provision for adjustable pre-set stops for refocusing picture of Kodachrome duplicates when changing from standard to non-standard-position films.

(e) *Lack of Accessibility for Proper Cleaning*.—This is a most important feature, universally recognized in 35-mm theatrical equipment and universally ignored in 16-mm projectors. In particular, there is not one widely distributed sound projector on the 16-mm projector market that has a readily removable and properly cleanable picture gate, although practically every 35-mm projector made in the last 20 or more years has had this feature.

(6) The mode of use of the screen must be improved, having regard to the fact that it can act upon the mind of the spectator

(a) By faithful presentation of the subject.

(b) By the representation of the subject simplified.

(c) By the representation of the subject in sections.

(d) By the representation of the subject intensified, magnified, speeded up, slowed down, built up by degrees, or superposed.

These different methods must be employed according to a logical scheme, taking into account the subject to be dealt with and the specific character of the audience to which the film is planned to be shown.

For training films it is of utmost importance that the exhibition and use plans for a film be fully completed before the first camera exposes the first foot of film. Maximum effectiveness presumes the gearing of the subject matter of the film to the audience.

(7) The screen is a valuable means of suggestion; it will be used as a time-saver, often a valuable one, in putting across all matters that depend largely upon visual memory.

The lighted screen in the darkened room compels concentration upon the material presented. It is not only possible to put across details of mechanisms and their operation, but also to explain the coordination of activities that can not in the usual course of events be directly observed. This field is potentially a very productive one for industry as well as for our Armed Services.

(8) In order to economize effort and to save expense in making films, and to derive maximum profit from them, it is advisable to decide definitely beforehand to what extent regular photographing and animation are, respectively, to be used. Due to the high cost of animation in comparison with regular photographing, animation has been used to a much smaller degree than in many cases seems desirable for maximum effectiveness; however, films made in the last year have shown a definite improvement.

THE THREE-YEAR INTERVAL FOR THE 16-MM COMMERCIAL LABORATORY

The 16-mm commercial film laboratory has "cleared decks" in the past three years; in order to make way for a large volume of high-quality prints in Kodachrome and fine-grain black-and-white film it has eliminated all extraneous activities. It no longer prints 35-mm Kodachrome or black-and-white slide-films; it develops no 35-mm film and makes no 35-mm prints whatever. The precious production capacity formerly taken up by this variety of activities is now devoted entirely to 16-mm high-quality print production. Needless to say, this action has made it possible to increase greatly the output per man-hour and per dollar, and with a material improvement in technical quality. In the case of Precision Film Laboratories, it is possible to take any production print and project it with theatrical satisfaction with a technically complete arc projector upon a 12-ft

screen; not only the sound but also the picture will be of theatrical quality. And it should be so; the inherent resolution of today's best materials with proper handling is entirely adequate by present-day standards.

PRESENT-DAY 16-MM FILMS

The majority of 16-mm films processed today in the 16-mm commercial laboratory are of the training or educational type which are taken silent and use an "off-stage voice" or commentary sound-track rather than synchronized sound. Since we are a nation at war, large numbers of prints are needed from each subject—and simplicity and speed are the keynotes in the production of these direct and to-the-point films.

The Original Picture Film.—Sixteen-mm originals are usually direct positives; either black-and-white reversal or Kodachrome. These direct positive materials are almost ideal for the job at hand. The dirt and scratches usually accumulated in usual careful handling are quite objectionable when negative is used as the original material. In direct positives, however, these imperfections are practically invisible and splices do not show. The intermediate negative and print (for black-and-white) permit an almost infinite number of high-grade black-and-white prints that are not only appreciably superior to 35-mm optical reductions as to graininess, but also far better as to softness and gradation due to the use of the negative-positive process in obtaining the final result. The advantages of direct positive materials are now so pronounced that negative-type materials have been practically eliminated in all applications where a large number of copies is required.

Direct positive materials are not ordinarily developed by commercial film laboratories; since the cost of developing is included in the price paid for the film, developing is under control of the film manufacturer. This applies to reversal materials as well as to Kodachrome. Some independent laboratories are reversing positive film but the volume of this class of work at the present time is not large.

Materials.—There are two kinds of original Kodachrome available, "Regular" (which is intended for use in daylight) and Type A (which is intended for use in artificial light). The prime difference between the two is that if both are projected with the usual high-efficiency tungsten lamp, the color will appear correct as seen by daylight for

the Regular film and as seen by highly overvolted Photoflood No. 1 or No. 2 lamps for the Type A. Since the blue-sensitivity and the green-sensitivity of Type A are higher than that of Regular, while the red-sensitivity is nearly the same, it is easier to use Type A with a filter in daylight than to use Regular with a filter in artificial light, as the calculated speed of the Type A film so used does not appreciably change. Another advantage of Type A used with a filter in the outdoors is that the film is not subject to "haze trouble" caused by excessive ultraviolet and blue-violet. With proper color-temperatures, however, it is best to use Regular for daylight and Type A for artificial light.

Present-day reversal materials still give the impression that they are intended for the amateur who, according to a current fallacy, likes his film as fast as possible and as "hard as nails." In original reversal materials today, there is still a big need for a low-contrast, long-reproduction-scale material, since there is no such material on the photographic market and we have been struggling along without it for some five years. Agfa did manufacture a film called "Old Type Superpan" which was a long-scale material of beautifully low contrast, but it was unfortunately withdrawn from the market when the faster emulsions of the "Supreme" type made their appearance. The film manufacturer who supplies such material and incorporates in it the new emulsion improvements of the last five years as to grain reduction and speed will not only earn the blessings of a long-suffering professional market by reopening wide fields of usefulness but also should find it very profitable as well. All finer-grained reversal emulsions available today are of the high-contrast type.

Today's Compromise.—Critical professional film users have been aware of this situation for the past two years or more and have turned to Kodachrome as the original material for their black-and-white prints. Kodachrome has appreciably lower contrast than any finer-grain reversal film at present on the market, and in the opinion of its users, is well worth while despite its higher cost and lower speed.* From a production viewpoint its slower speed is a serious handicap due to the appreciably larger amount of lighting equipment necessary to photograph with it. It must be remembered that the mobility of the industrial camera is measured by the mobility of the lighting equipment required to illuminate the subject.

* See Appendix for further data.

The Work Copy.—The first step in handling developed direct positive originals is to make the usual work-print or editing copy. Basically, there is little here to describe except that the work-copy actually made depends primarily upon the functions it is to perform. It may vary all the way from a one-light copy made on positive stock and developed in a positive bath (with a negative viewing aspect) to a Kodachrome duplicate intended to show reasonably closely the color balance to be expected in the release duplicates.

One extremely important point should be made: while it is true that a beautiful photographic copy is not ordinarily required of a work-print, it is equally true that a cheap work-print may be the most costly element in the whole production process. If the original is scratched by careless handling or by printing in an improperly designed or maintained printer, all the effort made to obtain an otherwise excellent original is futile. Careless handling of originals during the work-print and editing stages have been a major cause for what might be called the high mortality rate of otherwise good films.

Both work-print and original picture are returned to the film maker; the next job at hand is the editing of the picture and the preparation of the sound-track. Generally speaking, the commercial laboratory does not edit film, as its function is to perform the essentially mechanical work of the copying process without attempting to do any "creative" work whatever.

The Sound Negative.—After the work-print is edited, sound is scored. While sound is recorded as a negative as in 35-mm, here again the procedure diverges widely. Sound is recorded upon yellow-dyed high-resolving-power film exposed through a blue filter; ultraviolet is undesirable as it causes inferior resolution. The harmonic distortion with an 85-per cent modulated sound-track of 400 cycles of density 1.5 can be kept as low as 1 per cent; with ultraviolet light and usual ultraviolet-type film-stocks in the same machine, it is difficult to get the distortion down to 6 per cent. The improvement in noise level of yellow-dyed film is likewise satisfyingly large. (Recently blue-dyed films have been introduced whose performance characteristics seem to be quite similar to those of the yellow-dyed film that has been in use for the past three or four years.)

The laboratory develops sound-film at standard time (which happens to be 6 minutes) for the standard negative density of 1.90. As accurate and complete control is essential to consistent high-

SOUND LOG SHEET

Tape To Can Which This Log Describes _____ Date: _____

From _____ To _____ Page No.: _____

(Company or Individual)

(Address)

(City and State)

Ordered By _____ Sound Man _____

Order Number _____ Microphone Man _____

Title of Film _____ Director _____

Location _____ Cameraman _____

Film: Make: _____ Emulsion and Coating No.: _____ Winding A-1 B-2 Direction L to R R to L

B-M Recorder Type No.: _____ Serial No.: _____ Lamp No.: _____ Filter: _____

B-M AGN Amplifier Type No.: _____ Serial No.: _____ Current: _____ Increase Decrease

B-M Recorder Amplifier Type No.: _____ Serial No.: _____ Current: _____ Amps.

B-M Power Supply Type No.: _____ Serial No.: _____

Microphone: Name and Type: _____ Setting: R - D - C

Filters: Low Pass Type No.: _____ Serial No.: _____ Others: _____

Scene No.	Take No.	Footage Start	Footage Stop	Scene Seconds	Lamp Current	Mike Setting	Main Gain Setting	Sinc. or Non.	REMARKS

Exposure Test _____

INSTRUCTIONS TO LABORATORY: Develop test (last _____ feet on outside of roll) at standard time. Develop track accordingly; this film will be used for Black and White Color

Test Dev. Time: _____ Test Density _____ Film Dev. Time: _____ Average Density: _____

Please fill in and return original to _____; retain copy.

Signature _____

FIG. 1. Sound log sheet.

quality results, all information transmitted between laboratory and film-maker is in writing. A typical sound log sheet is shown in Fig. 1. Comparable log sheets are made for picture; these too are sent to the laboratory to give the laboratory an opportunity to suggest improvements in lighting and similar matters of camera technique.

As part of the inspection routine, every sound negative is completely run and inspected at synchronous sound speed on a 16-mm film-phonograph and reproducing system having a 16-mm frequency

response characteristic quite like that of the Academy of Motion Picture Arts & Sciences standard 35-mm characteristic as described in the *Technical Bulletin* of October 10, 1938. The film-phonograph fulfills the requirements of such standard reproduction; it uses an optical system with an 0.4-mil slit produced by a microscope objective together with an 8-volt, 2-ampere exciter-lamp to provide the necessary mechanical rigidity of the filament to avoid microphonic noise. The exciter-lamp, together with the heaters of amplifier tubes operated at low level, is energized from a rectified power-supply to assure satisfactorily low noise and hum content. The amplifier drives a 2-way "horn-woofer" loud speaker system utilizing a conventional 400-cycle, 180-degree cross-over network. Needless to say, the combination is of better than theatrical quality, as is necessary in equipment to be used for judging sound quality critically.

A report of the inspection is sent to the customer, and, if indicated, methods of correcting difficulties and improving quality are suggested. If the recording is below par, the customer is advised to make a retake. Under usual conditions, the need of retakes is rare. It is interesting to note that distance from the laboratory is no measure of the quality of the resultant product; the great bulk of the exchange of information is arranged by mail; some of the finest work is turned out by film-makers located on the other side of the continent as well as by those within a stone's throw of the laboratory.

The Sound-Track Print.—After the negative has been approved, a sound-track print is made for checking purposes. This is in every respect the highest-quality sound-track print that can be turned out, as the quality of the release film is judged by this print. As in the case of all other 16-mm prints, it is made on fine-grain film.* It has been found impossible to make good sound-track prints with a contact printer; accordingly, all sound prints—both combined prints and sound-track prints—are printed on a one-to-one optical sound-printer whose slip with acetate base films is even less than the comparable 35-mm "slip" of high-grade non-slip printers with nitrate-base films. If we can judge by the papers in the *JOURNAL*, the sound-track printers for *Fantasia* were of the general type used for 16-mm; this type of printer had been in use for 16-mm printing for several years before the *Fantasia* equipment made its appearance.

The sound-track is then projected on the film-phonograph equip-

* Technical Appendix.

ment just as was the negative. The same man who checked the negative usually checks the print. While cases of defective sound-prints have been almost unknown for the last year, track-prints are still carefully checked, as they are often used for Kodachrome duplicating or for re-recording. Fig. 2 is a typical "pink" sheet, as we call our Technical Record Sheet. Fig. 3 shows the reverse side of the "pink" sheet; as will be noted, very little is left to the imagination when defects are described.

A PRODUCTION EXAMPLE

Assume that the job to be done is making Kodachrome duplicates at the same time black-and-white fine-grain prints are to be made. The film-maker ships to the laboratory the original edited Kodachrome, his Kodachrome work-print, the sound negative, and the sound-track print. These are accompanied by specific instructions concerning the reproduction required in key scenes.

Preparation.—The film is turned over to the Preparation Section, where it is first inventoried and then prepared for printing. This includes checking the marking and identification of the leaders and the inspection of splices and the checking of emulsion positions. As this work is the function of the film-maker and not of the laboratory, the film is returned to the film-maker for correction if incomplete in a major degree; if incomplete in a minor degree, the laboratory will, upon authorization, perform the necessary work. In the Preparation Section, the timing sheets for printing are made ready—and made to correspond with the identification leaders on the original films.

Sound Inspection.—The sound-negative and the sound-track print are turned over to the Sound Inspection Section and checked against the original recording log sheets and laboratory processing records ("pink sheets"). Since both sound-negative and track-print will be used for printing (one for black-and-white and one for Kodachrome), both are carefully checked to make certain that the film is in prime condition and that the sound is up to par. Both are then returned to the Timing Section with the report of their condition.

Timing of Picture.—The Kodachrome original is turned over to the timer; the procedure in timing Kodachrome is quite similar to that used in timing black-and-white. The timer determines the filter combination required, and enters this and the scene lights on the timing sheet. A pre-perforated timing strip is

PRECISION FILM LABORATORIES							TECHNICAL DATA	
Customer _____						Date Wanted _____		
REEL NO.	SUBJECT				NO. OF PRINTS	FOOTAGE	TYPE OF STOCK	REMARKS
16 m/m <input type="checkbox"/>	Negative <input type="checkbox"/>	Hold <input type="checkbox"/>	B. & W. <input type="checkbox"/>	RESULTS OF TESTS				
35 m/m <input type="checkbox"/>	Positive <input type="checkbox"/>	Return <input type="checkbox"/>	Color <input type="checkbox"/>					
Reversal <input type="checkbox"/>	Picture <input type="checkbox"/>	Sound <input type="checkbox"/>	Combined <input type="checkbox"/>					
Work Print <input type="checkbox"/>				First Print <input type="checkbox"/>		Subsequent Print <input type="checkbox"/>		Special <input type="checkbox"/>
Picture Printer # _____		Emul. # _____		Weston Filters or Gr. Glass _____		Contact _____		
Rho. Setting _____		Iris Setting _____				Optical 1:1 _____		
_____ Volt _____		Watt Lamp Used At _____ Volts				Reduction _____		
Head To Tail <input type="checkbox"/>		Tail To Head <input type="checkbox"/>						
Sound Printer # _____		Set At _____		Ampere With _____		Filter Emul. <input type="checkbox"/>		
VA <input type="checkbox"/>		White Light <input type="checkbox"/>		Negative Emul. _____		H. to T. <input type="checkbox"/>		
VD <input type="checkbox"/>		UG3 <input type="checkbox"/>		Negative Density _____		T. to H. <input type="checkbox"/>		
BG12 <input type="checkbox"/>						Print Density Desired _____		
Printed By _____								
Machine No. _____		Dev. Time _____		Bath _____		Gamma _____		
REMARKS _____								
Bath _____ Developed By _____								
Picture Density <input type="checkbox"/>		Track Density Read _____		Quality <input type="checkbox"/>				
Light <input type="checkbox"/>				Good <input type="checkbox"/>				
Good <input type="checkbox"/>				Bad <input type="checkbox"/>				
Heavy <input type="checkbox"/>				Fair <input type="checkbox"/>				
REPORT _____								
Date _____ Inspected By _____								
Leaders <input type="checkbox"/>		Can Reel <input type="checkbox"/>		Size <input type="checkbox"/>		REMARKS _____		
		Carton <input type="checkbox"/>		400 <input type="checkbox"/>		Date Released _____		
				800 <input type="checkbox"/>				
				1200 <input type="checkbox"/>				
				1600 <input type="checkbox"/>				
Released By _____								
Complete <input type="checkbox"/>		REMARKS _____				Date _____		
Incomplete <input type="checkbox"/>						Shipped By _____		

FIG. 2. "Pink sheet."

then made up from the timing sheet. Since Kodachrome is printed under a weak green safelight, it is necessary that all operations to be performed in the printing shall be done by automatic means to assure certainty in the result.

Sound Inspection of Originals.—It the meantime, the sound-negative and the sound-track print have been prepared and checked for

ever slight) will result in the making of a new sound-track print for duplicating purposes.

PRINTING

The Kodachrome Test Duplicate.—The Kodachrome original and the sound-track positive are now sent to the Kodachrome printing section. Kodachrome printing is kept apart from black-and-white printing since only a weak green safelight may be used for Kodachrome. In this light, it is almost impossible to read quickly due to the low level of illumination; for this reason, some form of automatic pre-set printing-light-change arrangement, such as our pre-perforated light-strip, is necessary for satisfactory scene changes despite the slow printing speed of some twenty feet a minute.

The Picture Printer.—The improvement in lens resolution shown by such projectors as the Eastman in comparison with the older models of other manufacturers, as well as the increasing use of arc projectors, makes high resolution a "must" on Kodachrome duplicates.* The printers used for this operation are step-contact printers having the movement claw within a frame or two of the aperture where the duplicate is exposed. Light-changing is effected through the customary notch in the original; in this case, however, the notch that effects the light-change automatically causes the pre-perforated strip to set the light-intensity of the particular scene being printed.

At this point, something should be said about picture printer design and its effect upon the resolution of the copy. Any conventional form of curved gate printer used for continuous picture printing can provide good "contact" for only one definite and specific shrinkage of the original with respect to the raw-stock used; this is determined by the radius of curvature of the gate. It was to avoid this handicap that sound-printers were forced to adopt the so-called non-slip construction in order to be practical for sound-printing purposes by accommodating somewhat wider shrinkage ranges.

Essentially, the same condition obtains in picture-printing, where the non-conformity of the original to the raw-stock is accentuated by the use of acetate-base materials. While there is little or no difficulty with originals due to different shrinkages at the center and at the edges when originals are stored loosely wound, a linear shrinkage of 0.1 per cent or less in an original when new increases to a shrinkage

* See Appendix.

of the order of 0.5 per cent in a relatively short time (less than six months). Since it is not unusual that a film-maker will expect to make prints from training films that are a year or more old, curved gate printer construction for Kodachrome picture printing is eliminated; the only commercial solution in high-quality Kodachrome production printing is slow-speed step-printing in a straight gate using a claw type of film movement. It is only in this manner that the contact printing ideal—that of printing in a still picture contact frame—can be reasonably well approximated with present-day equipment. All Kodachrome printed at Precision Film Laboratories is printed on such equipment. It is costly, but it preserves the quality of the costly original.

The Sound Printer.—Over a period of years, Precision Film Laboratories and its affiliated manufacturing company, J. A. Maurer, Inc., investigated the problem of 16-mm sound-track printing and came to the conclusion that ordinary curved-gate contact printing of 16-mm sound-film was hopelessly inadequate and that the usual non-slip types were not applicable to 16-mm acetate-base films. If a piece of 16-mm film is run between two rollers spaced even as little as four inches apart, the film will appear to tilt first one way and then the other; the effect seems aperiodic. It does not take much imagination to visualize what happens when such a film forms a loose loop (as is formed by the upper loop in a non-slip printer); such linear non-uniformity of one side of the film with respect to the other can not possibly produce good contact, especially with the very low value of kinetic energy provided by the film in motion. There would appear to be no other practicable solution other than to put both sound-negative and sound-positive under tension in their respective printing loops and to print optically between them. It is an open secret among designers that there are only a very few microscope objectives on the market that can cover a sound-track with proper field flatness and without appreciable illumination loss at the ends of the area to be covered; the design problem included much optical bench inspection of most of the microscope objectives commercially marketed. It is interesting to note that the lens selected as most suitable for the purpose was NOT made in Germany.

Optical sound-printing has several other advantages: it makes possible quick interchangeability of whatever color-filters we choose to use; the depth of focus of the optical system can be made large with respect to the amount of in-and-out-of-focus film wobble ex-

perienced in printing; and printing either emulsion-to-emulsion or base-to-emulsion can be accomplished at will. Last but not least, it provides an excellent means of placing an image of high resolving power upon Kodachrome duplicates; the only means commercially available that begins to approach the resolving power of the image that would be placed on Kodachrome by a recording optical system itself.

At this point, it might reasonably be asked why picture is not printed optically when optical printing of sound has shown such advantageous attributes. The answer is quite simple; suitable optics are not being manufactured and marketed. It has been extremely difficult to find suitable optics for the sound-track area of only one-tenth of an inch; any attempt to cover three or four times that area must be postponed until after the war; then, we hope, suitable optics will be marketed.

After the Kodachrome test duplicate has been printed, it is packed and shipped to the Eastman Kodak Company at Rochester for color developing. Only one print is made; production prints are not authorized until after the test print has been inspected and approved and the small corrections, if any, requested by the film-maker are incorporated.

The Black-and-White Duplicate Negative.—While the Kodachrome test duplicate is in transit, the original Kodachrome is turned over to the chief timer for black-and-white timing. A timing sheet for the black-and-white duplicate negative printing is then prepared; from this timing sheet another pre-perforated timing strip is made up. Within the last two years or so, we have found it practicable to use the identical pre-perforated timing strip for the black-and-white duplicate negative that was used for Kodachrome printing. This has been possible since we use the same kind of printer, only one make and type of release-print fine-grain film—with accurate gamma and density control; and only one make and type of fine-grain duplicate negative material*—also with accurate gamma and density control. The film types used were selected on the basis of suitability for the intended purpose; strange to relate, all three major film manufacturers are represented as each seems to have a specialized technique in a specific material which places the particular product “way out front.”

* See Appendix for further data.

The Black-and-White Combined Test-Print.—If the duplicate negative is carefully made (and the Kodachrome original properly timed for printing), the resultant black-and-white duplicate negative is capable of producing highest-quality release-prints without any picture light-change whatever in the release-printing operation. Here again, the same kind of printers are used as for Kodachrome printing; step-contact printers with straight gates for picture and optical one-to-one printers for sound. All films that have been shown to the Society in the last two years by Precision Film Laboratories, by J. A. Maurer, Inc., or by any of the customers of Precision Film Laboratories have been printed in the manner described. Needless to say, considerable effort and planning were necessary to put the system into operation commercially, and a number of practical details had to be worked out to integrate the procedure. As a production matter, this kind of procedure seems to be today's solution of the problem of high-quality mass-production 16-mm black-and-white printing.

The Black-and-White Fine-Grain Release Print.—As soon as the black-and-white test-print is inspected by the film-maker, black-and-white protection sound-track prints are made; new duplicate negatives are made also (for parallel release printing and for protection) and the black-and-white release-prints are "ready to roll." The original sound-negative is ordinarily used in all release printing; it is not unusual for as many as a thousand or more prints to be made from the sound-negative original. With machinery properly designed, maintained, and operated, sound-negative deterioration should be almost minute. In laboratories that do not specialize in 16-mm film, here again the "mortality" rate runs quite high.

The Color Duplicate.—In the meantime, the color test duplicate has been returned from color development by Eastman Kodak Company and is ready for inspection. It is screened by the timer together with the film-maker; the timer then indicates on his timing sheet the corrections desired. A new pre-perforated timing strip is made in accordance with the corrected timing for the release color duplicates. It is not unusual to make as many as two hundred Kodachrome duplicates from the same original; the uniformity from one duplicate to another is just about as good as the color development uniformity in Kodak-processing.

Multiple Color Duplicates.—Experience indicates that if printing machinery is well designed and well maintained, and if the film is

carefully handled by competent and well trained personnel, few printing "accidents" will occur and the two-hundredth duplicate of a Kodachrome original should be, if anything, even better than the first or second, due to the experience gained. Good machinery properly maintained and properly operated causes very little wear on an original film.

Multiple Black-and-White Prints.—With regard to black-and-white fine-grain prints, the same may be said. As the number of black-and-white prints required of a subject may run over a thousand, some form of parallel printing operation is necessary for volume output. The procedure outlined needs but one further step: the provision of a suitable number of sound-track negatives for printing when a large number of prints is to be made in a short time. These are best obtained by re-recording; photographic methods are still decidedly inferior and should not be used if best and most uniform quality from print to print is required. At present commercial rates, sound-tracks can be re-recorded by competent and properly equipped 16-mm studios for as little as \$35 to \$50 per 400-ft reel; where a number of identical copies is to be turned out, the price may be even lower. As it is not unusual for a re-recorded negative to be used for 500 or more prints of the same subject, the addition of only some 7 cents per print to the printing cost due to re-recording is one of the cheapest kinds of good sound-insurance that money can buy.

Kodachrome and Black-and-White Protection Prints.—When a large number of prints is to be made from an original Kodachrome, one of the first matters for consideration is that of "protection prints." In our recent mad rush into 16-mm prints (from whatever originals), we have paid the usual lip service to protection prints but have not been especially concerned whether they fulfilled their intended function or not. If it is remembered that a protection print has as its function the making of further prints in the event that the printing master is damaged, not only would considerably more care and planning be used in their making but also they would command a much higher price. To provide properly for protection prints, we need not only protection for the picture but also protection for the sound. In the case of the picture, the best color protection print is a selected combined duplicate from the production run. No two prints are absolutely identical in quality; if every color duplicate is completely projection-inspected (as is absolutely necessary for accurate quality control of the product) it does not take an intelli-

gent inspector very long to select one of the best color duplicates of the production run. As protection for the black-and-white prints, it is advisable to make additional dupe negatives at the time the extra dupe negatives are made for the black-and-white print run. In general, the number of additional dupe negatives made as protection should be a percentage of the total number of prints expected after the initial print run is completed.

For protection of the sound, the original sound-track print used for re-recording the multiple black-and-white re-recorded negatives is the best protection possible. If this is in any way scratched or otherwise damaged, a new print (sound-track only) should be made. It is always possible at a later date to re-record from that positive should new printing negatives be needed.

Specific Recommendations for Protection Prints.—In the case of a production where a large print run is planned for both the Kodachrome and for the black-and-white, let us say 200 Kodachrome duplicates and 1000 black-and-white prints, the following protection prints would be desirable:

(a) Two Kodachrome combined duplicates (to be used as printing masters in the event of loss or damage to the original picture).

(b) Two black-and-white sound-track positive prints of the original sound-negative. (One of these would be printed emulsion-to-emulsion and the other printed through the base.)

(c) Three new black-and-white duplicate negatives.

All of these, with the possible exception of (a), should be made at the *start* of the release printing run.

Reasons for These Recommendations.—(a) The combined duplicates to be made can be considered reserve master duplicates; one or the other would be used for printing further release runs in the event of loss or damage of the original. It is to be noted, however, that since these films are contact-printed, second-run duplicates so made would have the standard emulsion position while the original-run duplicates will have the non-standard emulsion position.

While there is appreciable photographic loss in release duplicates made in this manner from a master protection copy, it is surprising how satisfactory such copies may be if the original was excellent and the copying work accurately controlled. It is not unusual for such secondary-run duplicates to provide better screen quality than the average first-run duplicates made in laboratories that do not specialize in 16-mm work.

(b) One sound-track positive of the two recommended is intended as a protection sound-positive to be used in printing additional first-run Kodachrome sound-duplicates from the original Kodachrome. In addition, this positive may be used also for re-recording additional sound-negatives for further black-and-white release runs.

The second sound-track positive is intended as a protection sound-positive to be used in printing second-run Kodachrome sound-duplicates from the master protection Kodachrome copy.

(c) The black-and-white duplicate negatives recommended are to be used for later black-and-white release runs; new duplicate negatives as made for release-printing purposes are preferably placed in storage and the older ones removed from storage and used. In this manner, the optimal state of preservation is maintained.

Storage of Protection Prints.—Unfortunately, one major factor that is responsible for the poor quality of the 16-mm prints at present being purchased in very large quantity by the Government for training and related purposes, is the absence of an intelligent protection-print policy. A suitable policy encompasses not only a definite plan as to how and when and with what quality protection prints are to be made, but also where such prints are to be stored. While much specifying of protection prints is done, the actual problem of *where* and *how* such prints are to be stored has been unceremoniously dropped into the laps of the release-print laboratories. This has been a carry-over from peace-time practices when laboratories used film storage as a factor in the competition for business.

The laboratory is NOT the proper place to store these protection prints; they should be stored by the film-maker himself, preferably on his own premises, where they are NOT out of sight and out of mind.

If the recommended protection films are stored approximately one week in the ordinary way and, at the end of the interval, placed in individual properly marked film cans and mounted on cores somewhat loosely wound, they will have dried sufficiently to be ready for storage. The can should be thoroughly dried (carbona will both clean and dry) and the film put into it. The can is next sealed with Kodatape or other adhesive of equivalent sealing ability.

If these cans are then stored in an electrical refrigerator whose temperature is set for about 50 degrees, all indications point to suitable storage for both the Kodachrome (image deterioration is essentially inhibited) and for the black-and-white films. In both cases,

shrinkage is also essentially inhibited; although the film may shrink somewhat when later taken out of the can, the shrinkage rate will be slow enough to permit the use of the film at least for a period long enough to permit making the desired prints. The storage characteristics of 16-mm films have improved considerably in the last few years, and still further improvement will doubtless come after the war is over.

Technical Requirements of Protection and Other Good Prints.—In the JOURNAL there are numerous papers on methods of measuring and reducing residual hypo. There have also been occasional references to the use of film “preservatives.” Unfortunately proper washing and drying of films is the exception rather than the rule; it must be remembered that a protection print provides no protection whatever unless it is properly washed and dried.

“Green” Film.—On April 14, 1939, the Research Council of the Academy of Motion Picture Arts & Sciences issued a *Technical Bulletin*, “Report on Film Preservative Tests,” which describes “green” film:

“Treatment given to release-print film after it has been printed, developed, and dried is commonly called ‘film preserving,’ and the processes by which this treatment is given are known as ‘film preservative’ processes.

“The gelatin of freshly developed film carries a high percentage of moisture in its pores and as long as this condition prevails is known as a ‘green’ emulsion. A so-called ‘green’ emulsion is quite soft and the slightest abrasion will cause a scratch. These scratches widen out as the gelatin dries, and cause the ‘rainy’ effects seen on the screen in the theater.

“As film with ‘green’ or soft emulsion passes through a projector, it leaves small deposits of emulsion on the tension shoes at either the aperture plate or the sound-gate, unless the tension shoes are kept thoroughly lubricated. Such deposits build up resistance to free passage of the film over them, and scratch the film during projection.

“When the moisture in a ‘green’ emulsion is withdrawn too quickly, the gelatin shrinks and the film warps or buckles. If too great an amount of moisture is withdrawn from the gelatin, the film becomes brittle, loses its pliability, and is easily torn while being projected.”

The subject of green film is ordinarily considered “delicate;” it is too often explained away rather than investigated. It is not unreasonable to believe that a major source of difficulty with such films as those untreated films described is just plain improper drying in the drybox of the developing machine. If one attempts to project an ordinary mass-produced low-price 16-mm “green” print made

under the average Government contract, it will not even go through a projector without some form of film "preservative" or lubricant.

There are two ways to look at the problem of green 16-mm prints: one is to accept improper washing and drying as a fact, and hope that a film "preservative" will accomplish the miracle; the other is to wash and dry the film properly. This job is *not* impossible; in our laboratory we have been 100-per cent projection-inspecting film in a matter of minutes after it is removed from the drybox take-up of the developing machine, and no "film preservative" whatever is used to "ease" the film through the projector. The reason is simple: the film when so washed and dried is *not* green. This procedure is not an innovation; the drybox is merely several times as long as the developing tank and, in addition, excess hardener is used in the hypo. In the average case, the drybox of the developing machine is only about one-fourth of its proper length and proper cubic-foot content as determined by the speed at which it is currently operated. It would seem the better part of wisdom to reduce our breakneck speed in order to tighten up on our inspection and improve our quality. It has been too often considered competitively advantageous to run machines at 400 feet per minute (in order to cut prices) when a fraction of the output in the form of really *good* quality films would far better serve the ultimate purpose.

A good rule to follow is that if a projector will not project an untreated new film satisfactorily, there is something wrong with the film (most likely), something wrong with the projector (less likely), or both. If Government specifications will require that films be projection-inspected and approved immediately after removal from the developing machine and *prior* to any "vaporating" or "preserving," there will be a remarkable increase in the life of prints purchased for circulation as well as a great reduction in the waste of film, chemicals, and labor now resulting from the scrapping of films that die long before their normal life span should be over.

The importance of proper washing and drying is only now beginning to be appreciated. If we project a carefully processed fine-grain film on a 12 or 15-ft screen with an arc projector such as a Bell & Howell equipped with sound and picture optics of Eastman Kodak quality, the film must lie perfectly flat in the gate or in an accurately predetermined position if the screen image is to be as satisfying as in 35-mm theatrical projection. This is no chore when films are properly washed and dried; unfortunately, proper washing and drying

are not as widely done as we would all like. This is another point, incidentally, where it is possible for a laboratory to "cut corners" in order to cut price.

High-quality 16-mm prints can now be obtained in fair volume but, as always, specialization is required properly to accomplish the intended result. Ordinary positive film does not have sufficient resolution to provide the performance specified for 16-mm films in 16-mm projectors; fine-grain films properly processed do have sufficient resolution, not only for the picture but also for the sound. For the sound, only optical one-to-one printing can provide suitable resolution.

When properly processed fine-grain films are used in properly designed, properly maintained, and properly operated projectors, the result is of theatrical quality and suitable for audiences (in proper auditoriums with proper screens and proper acoustics) up to about 500 or 1000. If the result in a particular case is not satisfactory but the machinery, auditorium, *etc.*, are known to be up to par, the film then becomes suspect.

APPENDIX

Notes on Fine-Grain Film and Its Processing in a Commercial 16-MM Laboratory

General.—While the contracts let by the Government for present-day bulk printing of war films are quite long and complicated and usually have a long and intricate questionnaire as an integral part, a study of the release-prints made under such contracts seems to show on the whole a disregard for technical quality. In the past emphasis has been placed upon quantity and low price in an effort to get out the work; one of the possible causes for this one-sidedness may well have been the paucity of reliable published data concerning the resolving power of film materials developed in commercial developers.

It has long been recognized that the film to be used for a particular purpose should be capable of clearly rendering the very fine lines of the image to be reproduced—whether the image be of picture, of sound, or, for that matter, of any other form of photographic intelligence. Generally speaking, the greater the resolving power (minuteness of detail—measured in lines per millimeter) of the films and machinery used in the making and showing of a sound-film, the better the quality of the performance seen and heard by the audience. Although the industry recognized the importance of resolving power, manufacturers were reluctant to publish resolving power data or to attempt to discuss the subject in other than qualitative terms. "Fine grain" was considered laudable; but there was no way for a film user to determine how fine "fine grain" had to be.

A convenient quality datum for 16-mm projection is the quality obtained in the conventional 35-mm entertainment motion picture theater.¹ Projection equipment, both picture and sound, have been standardized and even the theaters themselves have been considered for standardization. Sound has been standard-

ized; the projection equipment characteristics published by the Academy of Motion Picture Arts & Sciences have been an effective and reliable guide for several years. With this convenient reference, it is only necessary to extrapolate from the experience of the larger-size film into that of the smaller. If we wish to match the quality found in the entertainment motion picture theater when we project 16-mm prints, the latter prints must be capable of rendering all the detail of the larger film. This is accomplished, so far as the print raw-film is concerned, when the detail-rendering ability of the 16-mm positive is equal to that of its 35-mm counterpart. The resolving power of the 16-mm positive film must, therefore, be numerically equal to that of the 35-mm positive film multiplied by the ratio of the film areas. Since the area to accommodate the image on the 35-mm film is $2\frac{1}{2}$ times that available to accommodate the image on 16-mm film, the resolving power of the 16-mm film in lines per millimeter must be $2\frac{1}{2}$ times that of the 35-mm film for equivalent results.

The industry has been most fortunate recently in obtaining authoritative published data on the resolving power and other characteristics of Eastman film materials.⁸ The data presented now make it possible to judge quite reliably in a quantitative way the most suitable Eastman material for a particular application. The remainder of this Appendix will be devoted to the practical application of these data and to the suitability of the various materials for their intended purposes. Throughout this discussion it should be borne in mind that the difference between 35-mm film and 16-mm film of a given emulsion type is merely the width to which the material is slit; Eastman 1301 ordinary positive 35-mm film, for example, has the same emulsion as Eastman 5301 ordinary positive 16-mm film.

Resolving Power.—Since the resolving power of Eastman 1301 is 55 lines per mm, it is apparent that a 16-mm positive material must have a resolving power of $55 \times 2\frac{1}{2}$ or $137\frac{1}{2}$ lines per mm or more, for equal or better performance. According to this criterion, Eastman 5302 fine-grain positive, while it is a fine-grain material, is not fine enough for the purpose; its resolving power is only 90 lines per mm. It is obvious, therefore, that for detail-rendering equal to that of the 35-mm entertainment motion picture theater, Eastman 5302 fine-grain will not qualify; however Eastman 5365 fine-grain positive has a resolving power of 150 lines per mm, a detail-rendering ability considerably beyond the minimum required. For detail-rendering ability equal to that of the 35-mm entertainment motion picture theater, Eastman 5365 is satisfactory in 16-mm.

From these figures, it should be obvious that the use of 16-mm ordinary positive materials such as Eastman 5301, Dupont 600, Agfa 220, and others of similar resolving power, can not produce results on a 16-mm screen that are at all comparable with the results found on the usual 35-mm entertainment screen. The resolving powers of all are of the same low order. However, that while Eastman 5302 does not qualify, it is to be definitely preferred to material of lower resolving power.

Dupont has not published data on a comparable basis. It is known, however, that Dupont 605 fine-grain positive has resolving power of similar order to that of Eastman 5302. It is to be hoped that Dupont, Agfa, and the American Gevaert Company will soon publish similar data on a comparable basis so that materials may be intelligently selected for their intended applications.

The Practical Aspects of Application.—Theoretically, to preserve all the detail of an original film, it is necessary that the resolving power of every intermediate

material and machine and of the release-print material be as high as possible with respect to the resolving power of the original. This goal, while sought after, is only approached; we measure our achievement by the size of the gap between our practical result and our ideal.

Cost vs. Speed.—It is true that fine-grain materials are inherently slow photographically; it was for this reason that Dupont, in referring to Dupont 605 film in their brochure "Sixteen Millimeter Dupont Motion Picture Film," stated, "To date it has been impossible to get sufficient light for reduction printers to use this slow film for prints from 35-mm negatives." If the same developer and the same printing machine operating at the same film speed is used for 605 as for ordinary positive, the statement is true especially for conventional designs of machinery. This film can be used, however, if the proper compensating steps are taken in the proper amount: (1) increasing the energy of the developer; (2) increasing the intensity of the light-source or improving the efficiency of the optics of the exposing system; (3) reducing the linear speed of the film through the printer to increase the exposure time by the proper amount. Just how the compensating steps are to be apportioned is a matter of designer's choice; regardless of the balance finally chosen, the cost of fine-grain printing and developing is going to be higher than the cost for ordinary positive.

Gamma.—On occasion we hear the remark "I tried fine-grain film and it didn't work." Further investigation usually shows some lack of understanding of the fundamentals of film technique. One common failing is the lack of appreciation of the importance of overall or print-through gamma.

If we desire good gradation in the picture image, it is important that we plan quantitatively how to obtain it—we must avoid the common fault of "piling up" contrast in each successive-processing step through which the film passes. Fine-grain positive has higher contrast than ordinary positive and a compensating reduction in gamma must be made at some earlier stage if "washing out" is to be avoided. It is just as important in 1943 to avoid "piling up" contrast by the indiscriminate use of high gammas as it was in 1929 when we first began to appreciate the real significance of the term. Most of the 16-mm prints made under the Government bulk printing contracts exhibit an overall or print-through gamma far too high for even ordinary positive film; the use of the same techniques in connection with fine-grain materials can not but result in failure. Much could be accomplished to correct this condition if Government contracts would stress *overall* gammas; a very simple qualifying test for any laboratory desiring a Government contract would be to make a spliced test-roll of 50 feet containing the original and three sections of a reproduction from the same reversal original in sequence—the first, the positive print from the first dupe negative; the second, the print from the dupe negative of the first positive print; and the third the print from the dupe negative of the second positive print.

Contrast Control.—It has been said that one of the most advantageous characteristics of negative-positive processing is the control of overall gamma. This excellent method is of no value, however, if it is not used—and most of the 16-mm prints show little evidence of its use. If fine-grain release-print materials are inherently more contrasty than ordinary positive, it is obvious that a fine-grain print made from a particular original will be more contrasty than its ordinary positive counterpart, whether the original be 35-mm or 16-mm. The original negative must be made "softer," or an intermediate master positive and inter-

mediate duplicate negative of gamma product less than unity must be made, to correct for the expected contrast increase. Once again the method chosen is a matter of designer's choice, and once again, regardless of the method chosen, it will cost a little more to do the job properly with fine-grain film.

Contrast control in direct 16-mm black-and-white is obtained by the original reversal (Kodachrome)-duplicate negative-fine-grain positive processing method. The starting point is a direct positive; the number of steps used is one less than ordinarily needed for optical reduction from 35-mm. In the direct 16-mm case, it should be obvious that print contrast is controlled almost entirely in the making of the intermediate duplicate negative. The most suitable Eastman material is Eastman 5203 duplicating negative; it has a resolving power of 110 lines per mm, which, while a little shy of the goal, is sufficiently close for practical purposes.

Kodachrome.—Kodachrome, it should be noted, has been unjustly accused of quality inherently inferior to that of black-and-white prints. The data presented show the opposite to be true in the case of ordinary positive; Kodachrome has a resolving power of 75 lines per mm; Eastman 5301 ordinary positive has a resolving power of only 55 lines per mm. If sound or picture reproduction in Kodachrome duplicates is poorer than in black-and-white prints on ordinary positive, the fault should be sought elsewhere than in the material.

The following table is abstracted from the Eastman publication² referred to; the gammas specified are considered representative of good practice by Eastman Kodak Company but are not necessarily used by Precision Film Laboratories.

Type Number	Resolving Power Lines per Mm	Gamma	Developer
1301	55	2.0-2.20	D-16
5302	90	2.40-2.60	D-16
5365	150	1.20-1.60	*SD-21
5203	110	0.60-0.70	*SD-21

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THE PROJECTION OF MOTION PICTURES*

HERBERT A. STARKE**

Summary.—*The final phase of motion picture production is in the theater, and the success of this phase depends upon the technique of projection and the condition of the projection equipment.*

The paper discusses in considerable detail the importance of proper maintenance, the types of light-sources, and other factors of importance to good projection.

The final phase of a motion picture production is in the theater. All the preparation and expenditure of money involved in its creation have now been reduced to so much film footage. It is now in the hands of the projectionist, with whom lies the responsibility of transferring the material to the screen, through the medium of projectors and a source of light. Motion pictures are an illusion, and are intended to convey realism to the screen.

Upon the arrival of the release print, the normal procedure in first-run theaters is a careful inspection and measurement of the entire footage. For several years, the exchanges have been doubling up the reels of features for shipment. This duty is performed for the most part by girls in the exchange. In other words, the composite film is delivered to them on spools from the laboratory; they in turn mount the *A* and *B* sections on 2000-ft reels. Our experience has been that in many cases, this very important procedure is not properly handled. Most of the splicing is done with small mechanical splicers, which is allowed to become worn and out of alignment, with the result that inaccurate splices are made. Many of the girls engaged in this work do not realize the importance of properly blooming out splices. The splicing lacquer is allowed to become thick and slow-drying; and as

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** RKO Service Corp., Hollywood, Calif.

re-winding proceeds, deposits from the wet application are smeared on the track over several wraps. This necessitates cleaning with a lacquer remover, and invariably the splices are removed. Under no circumstances are the shipping reels used; they are, for the most part, badly bent and unfit for use. Most of the best theaters are equipped with cast aluminum reels, upon which the film material is mounted for the duration of the engagement.

It was the practice of first-run theaters in the early days of sound to conduct complete rehearsals before the opening of new pictures. The chief projectionist checked the volume from the auditorium, cues were made, and a general knowledge was acquired of the complete show. Today, unfortunately, this practice is not usually followed, with the result that the new shows are opened without the crew's having any accurate knowledge of the volume required. They depend solely upon booth monitoring.

Projection room routine will vary from theater to theater. Nevertheless, certain duties must be performed daily. Of great importance are the inspection and cleaning of the following units:

- (1) Projector mechanisms.
- (2) Upper and lower magazine valve assemblies.
- (3) Optical systems.
- (4) Lamp houses, contacts, and all component parts.
- (5) Take-ups and belts. Proper oiling with manufacturer's specified lubricant. Many projectors have been ruined by inferior oils.
- (6) Inspection of sound system.
- (7) Inspection of generators or rectifiers. Motor switches must be replaced at regular intervals. A failure here may cause interruption of the performance.

It is important that the light from each projector be checked on the screen for intensity and color, and at the same time, image alignment should be checked. Every effort should be made to ascertain that the shutters are perfectly timed; slight bleeding that may not be observed from the projection room will cause loss of definition.

There appears to be considerable lack of showmanship today, and the absence of lighting effects is noticeable. The general procedure is to work out a schedule, the starting time is determined, and the show is on. The practice of giving away cash and other prizes, in many of our *de luxe* theaters has not enhanced the production but rather has cheapened it.

The success of the presentation depends largely upon technical conditions often beyond the control of the projectionist. The equipment in many of our theaters today is inadequate, particularly with respect to the available light. Theater managers seem to be reluctant to seek proper advice when purchasing lamp equipment, and false economy often results in inadequate projection.

Light sources may be divided into three categories: (1) the largest theaters require condenser-type high-intensity arcs; (2) the intermediate theaters the *Suprex* type; (3) and the small theaters the 1-kw a-c or d-c types. Due to its yellow color and low intrinsic brilliancy, the low-intensity arc is being rapidly replaced by an intermediate type of non-rotating high-intensity arc having a color value approximating the white light of the rotating and non-rotating high-intensity arcs. The reflected screen light depends upon the character of the source, the optical system, and the reflectivity of the screen; and last but not least, upon the efficiency of operation. To the projectionist falls the task of coordinating these elements into a single, smoothly operating whole.

Dense prints are quite common today, and it is also becoming the practice to increase the auditorium illumination. Smoking is permitted in many theaters, tending to decrease reflectivity of the screen. The projectionist in the large theaters using the *Suprex* equipment instead of the high-intensity condenser arcs will often increase the arc wattage beyond the rated capacity of the carbon trim in an attempt to increase the brightness of the picture. He then encounters a disproportionate increase in carbon-burning rate, often beyond the feed rate of the arc control mechanism. Operation then becomes critical and efforts at manual control prevent the arc from establishing itself on a stable basis.

There has been a tendency, particularly on the West Coast, to increase the picture size without adding to the illuminations, whereupon a reduction in brightness and contrast results. Graininess is also noticeable, and all these factors lessen the value of the front rows of seats.

Operating difficulties may be encountered with the rotating high-intensity lamp, due to pitted or burned contact brushes, loose and dirty lead connections, excessive voltage at the arc. The carbon manufacturers' specifications should be rigidly followed. The lamp house should be ventilated, if possible, with a separate exhaust fan, and dampers put into the stack in such a manner as to control the

travel of air without impeding the passage of waste materials of arc combustion.

The *Suprex* and the 1-kw types of non-rotating high-intensity lamps are operated at small arc voltage and current. Hence, they are sensitive to drafts. Modern lamp houses are designed to have sufficient ventilation under ordinary conditions, but close control of the amount of air passing through the lamp houses into the stack is essential for trouble-free operation. Abnormal draft is caused by excessive ventilation of the projection room, back-draft from certain types of rear shutters having cooling fins, and down drafts from chimneys lacking forced-draft ventilation. Excessive draft, unless very strong, does not usually cause flickering, but it does cause a movement of the arc flame, which becomes noticeable on the screen.

The non-rotating high-intensity arc, when properly burned, is almost rectangular in form, with the point of the tail flame directly above and not far behind the positive crater. If the tail flame wavers and is driven toward the front of the lamp house in an intermittent manner, excessive draft is usually indicated.

If it is not possible to control the draft with the stack damper, it may be necessary to restrict the ventilation entering the lamp house; or, if the trouble is caused by fins on the rear shutters, the fins may be removed. However, this procedure is not recommended, as the fins were installed to dissipate heat from the film and the film-trap assembly. It is suggested that the arc be protected by means of a heat-proof glass shield placed directly behind the rear shutters. It should be remembered, however, that adequate ventilation is necessary to protect the lamp house, and drafts should be restricted only to the point at which the arc will burn satisfactorily.

In order to maintain a rectangular arc shape, as described, it is necessary that the carbons be properly positioned, by raising and lowering the negative carbon until the gases are seen to escape from the top of the positive crater. For higher currents, the negative carbon tip should be slightly below the centerline of the positive, and in order to let the gases escape from the top of the crater, it may be necessary to allow the top of the positive crater to burn back as much as 0.32 inch.

Anything that disturbs the normal position or function of the arc, such as some types of carbon savers, or by burning the carbons too short, may result in screen discoloration, light reduction, or change in light distribution.

The optical system of the non-rotating high-intensity lamp is designed by the manufacturer to deliver the maximum amount of light, and the arc should be operated in a given position with respect to the mirror. Moving the positive crater toward the mirror 0.10 inch from its proper distance will result in a decrease in screen illumination of approximately 40 per cent when using a 7-mm positive carbon.

In order to avoid noticeable screen color difference, the arc should be struck three or four minutes before the change-over period and the position of the image of the positive crater should be adjusted before, not after, the change-over. In many theaters where false economy prevails, projectionists are instructed never to strike the arc on the incoming projector until the last minute. With this procedure, screen results are bound to suffer.

When illumination trouble occurs it is necessary to locate it with a minimum of delay. Unfortunately, it is often difficult to determine immediately whether or not the carbons are at fault, and some projectionists keep a few trims in a dry place to be used as a check. Later if trouble occurs, carbons being currently used are checked against these reserves. If the trouble persists, one may look elsewhere for it, such as in the current supply or in the condition of the draft. Rarely are the carbons found to be at fault.

With the releasing of productions on fine-grain stock, hopes were entertained that some of the lighting problems would be lessened. Experience in this respect has been, to say the least, very disappointing. The greater brilliance and contrast are readily apparent, but the stock used so far has a tendency to buckle. The phenomenon is very curious: it comes and it goes. A print may be used for a few days without trouble; then, for no apparent reason, the picture on the screen begins to weave in and out of focus. In other words, the photographic image will be out of focus.

The modern projector is designed to be adaptable to all types of theaters. There are, however, many mechanisms now in use, particularly in circuit houses, that should have been discarded years ago. Worn film-tracks and hooked sprockets are found in many of them, which are the causes of film damage in alarming proportions. Many projectionists have adopted the practice of speeding up their electric rewinds beyond the limits set by the manufacturers. This causes many fine scratches on the surface of the film, commonly called "rain," and should not be tolerated.

It is difficult to understand why so many owners and managers will

not hesitate to make large expenditures on new marquees, carpets, chairs, and on the general beautifying of the auditorium, all of which can not be fully appreciated in the dark, but neglect to maintain properly the most vital part of their theater—the projection equipment. The screen is allowed to become dirty and discolored. There are many methods of so-called resurfacing; few have proved satisfactory. The best procedure is to try to keep the surface and perforations free from dust and dirt. When discoloration does take place, the screen should be replaced. The difference in cost between an ordinary resurfacing job and a new screen is not comparatively great.

Many of the older theaters were constructed during the days of vaudeville and stage presentations. The picture was of secondary importance; consequently little if any attention was given to the planning of the projection room, which, with very few exceptions, were small and poorly ventilated. They were, in most cases, constructed high above the balcony to avoid the loss of seating space. The cost of redesigning them to present-day standards would be prohibitive.

Picture distortion and keystoneing are present. Squaring the picture image by aperture-plate correction improves the general appearance, but the situation is a serious handicap to good projection. It is unfortunate that such conditions prevail in many of our first-run houses.

Notwithstanding these and many other factors, projection has for the most part improved steadily.

In 1936 the Research Council of the Academy of Motion Picture Arts & Sciences recommended the standard leader and the placing of dots in the upper right-hand corner of the composition for change-over cues. This practice was adopted by all the large producing companies, and provides a successful means of properly changing from one reel to another. Yet there are still some projectionists who deliberately deface the ends of reels with cues of their own design, such as punch marks or crosses scratched into the emulsion, all tending to impair the print and detract the audience's attention from the subject being reproduced upon the screen. True, the laboratories do not provide standard cues on many short subjects, such as newsreels and trailers, and it is necessary that some sort of cue be provided. A small inexpensive cue-marker consisting of a template and a hardened steel scribe is recommended, for scribing a small circle at the upper

right-hand corner of the film image, at exactly the spot where the standard dots would appear.

Conservation is all-important today, and replacement parts will not be obtainable. It is therefore urgent that equipment should be properly checked and adjusted. There is no reason why an intermittent sprocket should not last at least three years, provided it is of the manufacturer's specifications and the tension pads and shoes are properly adjusted. Excessive tension not only shortens the life of the sprockets, but also causes undue wear throughout the entire projector mechanism. One method of increasing the life of tension pads and shoes is to have them ground perfectly true and then chromium-plated. This also eliminates the tendency of new (or "green") film to stick while being projected.

Space does not permit a complete discussion of the many important units that tend to make up the modern projection room. Projection may be termed the bottle-neck of the industry, and there is much that can be done in the projection room to assist in placing upon the screen high-quality pictures reflecting the great amount of labor, art, and expense that went into the making of the production in the studio.

APPLICATION AND DISTRIBUTION OF 16-MM EDUCATIONAL MOTION PICTURES*

F. W. BRIGHT**

Summary.—The proper distribution and application of 16-mm motion pictures require painstaking planning and continued follow-through. . With this in mind, the methods of distribution are considered with respect to the three major fields of business employing 16-mm pictures, viz., (1) public education; (2) sales training; (3) personalizing messages from home offices to field personnel.

The proper application and distribution of 16-mm motion pictures is not a hit-or-miss proposition. Rather it is an exact science depending almost entirely upon painstaking planning and continued follow-through.

Too often producers and users of 16-mm pictures neglect to give this phase of the program the necessary attention. Too much emphasis is placed upon achieving mechanical perfection in the picture, and too little upon the ultimate effect upon the audiences, with the result that the picture fails in the job for which it was intended.

Since 1934, when we distributed our first 16-mm public release, the results of this medium of visual and oral education have been excellent, because the application and distribution plans have been carefully considered well in advance of the release dates.

At present we are enthusiastically producing and using 16-mm films in three major fields—(1) public education, (2) sales training, and (3) personalizing messages from Home Office officials to our field personnel.

Public Education.—Before releasing any picture for the public,

* Presented at the 1942 Fall Meeting at New York, N. Y.; received October 25, 1942.

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the distribution is carefully planned, step by step. This procedure is demonstrated by one of our educational health releases. The first step in planned distribution is to arrange formal previews by recognized authorities on the subject. Invited to these previews are representatives of the local or state medical societies, key members of hospital staffs, dietitians, representatives of stand and local health departments, and others who have a real interest in the subject. After seeing the picture, they are asked to offer suggestions and criticisms. If the criticisms are of sufficient importance and are practical, we make the necessary changes. This procedure guarantees authenticity and saves us the embarrassment from justifiable criticism after release to the public.

The second step is a formal première of the picture. Even though it may be necessary to hold up the release date for some time, the picture is given its première at a national convention or meeting of a group who are vitally interested in promoting the subject. At this meeting, however, it is important that the picture be an integral part of the program rather than on a commercial exhibitor's basis. This showing gives us a good cross-section of public reaction, creates good will for our companies, and provides an excellent vehicle for publicizing the picture through newspapers, radio, and word of mouth.

The third step is the public announcement. Carefully worded copy is sent to selected trade publications whose readers will have a natural interest in the picture. Personal letters, including copies of the news release are mailed to a large list of individuals and organizations throughout the country. Simultaneously announcement is made to all our field offices and an article is inserted in our house organ which reaches some 25,000 agents.

After we have carefully followed these various steps, the picture is released publicly and a large number of requests automatically follow.

To increase distribution further, we have equipped twenty-five, strategically located field offices with sound projectors and screens. These offices then follow through on their local distribution plans, offering to project the picture to certain key groups and offering prints without charge, to others. Furthermore, each of these offices serves as a booking office and depository for the film. Their projection equipment, as well as prints, are inspected periodically and monthly reports of their showings are obtained. They maintain

their own schedules and any agents in their territories who are qualified to operate the projection equipment may borrow it without charge.

Proof of the effectiveness of this distribution plan for public releases is evidenced by the fact that one of our pictures alone was shown to more than 20,000,000 persons before it became too dated and was withdrawn from circulation.

Sales Training.—In showing sales training pictures, distribution volume is, of course, secondary to proper application. Like many businesses, we have a certain number of commissioned salesmen who either have had no previous selling experience, or at least are newcomers to our business. Following the war, all business employing large numbers of salesmen will be faced with the problem of attracting desirable representatives. Since the competition will be so keen, we feel that our experience now with motion pictures will be invaluable in this recruiting work.

Just as distribution is carefully planned before production of public release subjects, the application of sales-training pictures is also planned in detail before production commences. Sales-training subjects are broken down into two general classifications: (a) basic selling suggestions, and (b) technical sales training. The basic selling suggestions type is used for primary training of new men, and as refreshers for experienced salesmen. In these pictures, we include proper technique for pre-approach, approaching the prospect, organizing the details of a selling campaign, asking leading questions, and other details which even seasoned salesmen may neglect. Since the subject matter is usually trite, there is a tendency to treat it lightly, so the points are dramatized to an exaggerated degree. By carefully planning the material in these films, they are acceptable not only to our own personnel, but through our trade organizations, we can attract new salesmen to our companies. Technical training pictures for salaried representatives and more advanced agents provide an excellent medium for introducing new contracts, developing particular sales possibilities and dramatizing the benefits as well as the limitations of our contracts.

In the production of all sales-training pictures, we work closely with our sales department in deciding the subject matter, preparing the script, casting the actors, and other production details. While sound slide films and post-recorded motion pictures have a definite place in visual education, we have learned that lip synchronization

gives the best results, particularly in dramatizing sales interviews where voice inflection and timing are important. A close check is kept on the audience's reaction to these sales pictures and suggestions from our field representative is welcomed. Fortunately, we have little difficulty in learning how the pictures are received by our agents. Following nearly every showing, we receive letters, all of them apparently sincere and spontaneous, since criticism is made as freely as praise.

Personalizing Messages from the Home Office.—Because of restricted transportation facilities, we have had to curtail, to a great extent, visits to our field offices. Consequently, this has increased the need for localized educational meetings of branch office personnel and agents. By utilizing 16-mm lip synchronization we have been able to bring educational and inspirational talks by our key men to these local meetings. This year, for example, at our annual sales meetings, which are held in some twenty-five field offices, we reduced our traveling personnel to a minimum; yet at the same time, *via* motion pictures, took approximately forty of our officers and specialists to these meetings.

The sound projectors that we have placed in certain of our branch offices are always readily available for both sales training and personalized messages, and since they are portable, they can be used in not only the offices, but in hotels and other meeting places.

When we first released 16-mm motion pictures publicly, we attempted to supply all requests within a short time, but soon found that it was impossible. For example, we used nearly 600 prints of one highway safety film, and even this large number was insufficient. Moreover, some of our pictures are released exclusively in color and since they run eight hundred to twelve hundred feet, the cost of hundreds of prints is prohibitive. Rather than diminishing, the demand for pictures increased, and we had to limit the number of prints of each picture available. All our subjects are produced in kodachrome from which we make black-and-white dupes, and although some of them are released in color, all the sales training and most of the public releases do a satisfactory job in black and white. We now limit the number of prints to forty black and white and ten kodachrome. Black-and-white prints are then deposited in our branch office depositories and the remainder booked direct. In cases where color-prints are distributed exclusively, the entire booking and distribution are handled from our home office.

Naturally there must be exceptions to this plan. Shortly after Pearl Harbor, we produced a civilian defense picture in coöperation with the Connecticut Defense Council and intended it to be used only in Connecticut. However, we soon received requests from neighboring states, and the demand increased until today we are using sixty prints in all parts of the country. To help keep up with the demand for this and other pictures, after we have exhausted our budget on the picture, we make prints available at cost to interested non-commercial organizations. Local and state defense councils, service clubs, colleges, safety councils, and similar groups have purchased prints and in each case, we prepare a short credit title showing their sponsorship of the picture.

While we are planning to maintain our motion picture program as far as possible, the war has already made some changes and will undoubtedly affect our distribution and application materially. However, we hope to adhere to two main types of pictures—public education along the lines of conservation, health and safety; and education of our agents and others in our sales force. We are also experimenting with sales presentation pictures which our agents can take directly into the prospect's home or office and which will give him an opportunity to get and hold the prospect's attention with the power of 16-mm motion pictures. We have already made some progress along this line, and after the war is over, we shall be ready to use this new application of the motion picture medium.

FIFTY-FOURTH SEMI-ANNUAL TECHNICAL CONFERENCE

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

HOLLYWOOD-ROOSEVELT HOTEL, HOLLYWOOD, CALIF.
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There will be no special or prearranged ladies entertainment program during the five-day 1943 Fall Conference. However, a reception parlor will be available in the Hotel where the ladies may meet daily. The ladies are cordially invited to attend the functions of the Conference.

TENTATIVE PROGRAM**Monday, October 18th****9:30 a.m.** *Hotel Lobby; Registration.*

The program for the morning of this date will be announced later.

12:30 p.m. *Terrace Room; Informal Get-Together Luncheon* for members, their guests, and families. The luncheon program will be announced later.

Due to the hotel labor and food situation, it is imperative members procure their luncheon and dinner-dance tickets at the time of registering so that the Arrangements Committee may provide the necessary accommodations.

2:00 p.m. *Blossom Room*; **General Session.**

8:00 p.m. **General Session**; the location will be announced later.

Tuesday, October 19th

10:00 a.m. *Hotel Lobby*; **Registration.** Open morning.

2:00 p.m. *Blossom Room*; **General Session.**

8:00 p.m. **General Session**; the location will be announced later.

Wednesday, October 20th

9:30 a.m. *Hotel Lobby*; **Registration.**

10:00 a.m. *Blossom Room*; **General Session.**

2:00 p.m. Open afternoon for recreational program to be announced later.

8:00 p.m. *Blossom Room*; **SMPE Fifty-Fourth Semi-Annual Dinner-Dance.**
The program for the evening will be announced later. (Dancing until 12:30 a.m.; strictly informal business dress and uniforms only.)

Thursday, October 21st

10:00 a.m. Open morning.

2:00 p.m. *Blossom Room*; **General Session.**

8:00 p.m. **General Session**; the location will be announced later.

Friday, October 22nd

10:00 a.m. *Blossom Room*; **General Session.**

2:00 p.m. *Blossom Room*; **General Session.**

8:00 p.m. *Blossom Room*; **General Session and Adjournment.**

Conference Headquarters

The Pacific Coast Section Officers have selected the Hollywood-Roosevelt Hotel, Hollywood, Calif., as headquarters for the 1943 Fall Technical Conference with the following *per diem* rates guaranteed by the hotel management.

Room with bath, one person.....	\$3.85
Room, double bed, with bath, two persons.....	5.50
Room, twin beds with bath, two persons.....	6.60
Small suite, parlor, bedroom with bath, single or double occupancy.....	8.80

Room reservation cards will be mailed to the membership early in September, and should be returned immediately to the Hotel. All booked accommodations will be guaranteed when confirmed by the Hotel Management. Reservations are subject to cancellation at any time prior to the Conference.

Indoor and outdoor parking facilities will be available at the Hotel headquarters if desired.

The Conference registration headquarters will be located in the Hotel Lobby, and members and guests will be expected to register and receive their badges and identification cards. The registration fees are used to help defray the Conference expenses, and coöperation in this respect will be greatly appreciated by the Local Arrangements Committee.

The identification cards will provide admittance to all sessions at and away from the Hotel. They will be honored also at the following *de luxe* motion picture theaters on Hollywood Boulevard, in the vicinity of the Hotel: Fox West Coast *Grauman's Chinese* and *Egyptian* Theaters, *Hollywood Paramount*, *Hollywood Pantages*, and *Warner's Hollywood Theater*.

Eastern and Mid-western members who are planning to attend the 1943 Fall Conference should consult their local railroad passenger agent regarding train schedules, available accommodations, rates, and stop-over privileges *en route*. If a San Francisco stop-over is included in the trip to the West Coast, the Conference Committee suggests the Mark Hopkins Hotel on "Nob Hill." Reservations should be mailed to Mr. R. E. Goldsworthy, Assistant Manager of the Mark Hopkins.

Note.—The 1943 Fall Technical Conference is subject to cancellation if later deemed advisable in the national interest.

W. C. KUNZMANN
Convention Vice-President

IMPORTANT

Hotel reservation cards must be returned immediately. Otherwise the Hotel cannot guarantee accommodations.

Members intending to attend the Fifty-Fourth Semi-Annual Conference should make arrangements for their railroad accommodations immediately or at the latest one and a half months in advance of the Conference date.

SOCIETY ANNOUNCEMENTS

MAILING OF NOTICES TO MEMBERS OF THE ATLANTIC COAST SECTION

As the territory included by the Atlantic Coast Section of the Society extends from Maine to Florida and includes the Eastern and Central Standard Time zones (as the result of the discontinuance of the Mid-West Section), many of the members of the Section find it impossible to attend the monthly meetings and other functions. The situation has been considerably aggravated by the present difficulties of transportation.

For these reasons, as well as for reasons of economy, the Board of Governors, at the meeting held on May 3rd at New York, felt that notices of meetings, routine letters, and other material should be sent only to members of the Section residing in the New York metropolitan area, since it is from this area that the meetings draw practically all their attendance.

However, the Board provided also that members not residing in the New York metropolitan area but who wish to receive such notices, *etc.*, may have their names continued upon the mailing list of the Section by writing to the office of the Society, at the Hotel Pennsylvania, New York, N. Y.

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

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SYMPOSIUM ON THE

TRAINING FILM ACTIVITIES OF THE U. S. ARMY

Prepared by Members of the U. S. Army Signal Corps, Army Service Forces, and Presented at the Spring Meeting of the Society, at the Hotel Pennsylvania, New York, N. Y., May 6, 1943

The papers constituting the Symposium, in the order of their publication in this issue of the JOURNAL, are as follows:

- "Produced by the United States Army Signal Corps"; Capt. Halvor T. Darracott, U. S. Army Pictorial Service, Washington, D. C.
- "Some Psychological Factors in Training Films"; Col. M. E. Gillette, U. S. Army Signal Corps Photographic Center, Astoria, Long Island, N. Y.
- "Training Film Production Problems"; Lt. Col. Robert P. Presnel, U. S. Army Signal Corps Photographic Center, Astoria, Long Island, N. Y.
- "The Service Films Division of the Signal Corps Photographic Center"; Lt. Col. Emanuel Cohen, U. S. Army Photographic Center, Astoria, Long Island, N. Y.
- "Animation in Training Films"; Major Ellis Smith, U. S. Army Signal Corps Photographic Center, Astoria, Long Island, N. Y.
- "Sound Recording at the Signal Corps Photographic Center"; Major G. C. Misener, U. S. Army Signal Corps Photographic Center, Astoria, Long Island, N. Y.
- "Field Camera Problems"; Capt. Ray L. Ramsey, U. S. Signal Corps Photographic Center, Astoria, Long Island, N. Y.
- "Multiple Film Scene Selector"; Capt. Harry W. Leasim, U. S. Army Pictorial Service, Washington, D. C.
- "Training Film Distribution"; Lt. James D. Finn, U. S. Army Pictorial Service, Washington, D. C.
- "Training Film Utilization"; Mr. Boyd T. Wolff, U. S. Army Pictorial Service, Washington, D. C.

PRODUCED BY THE UNITED STATES ARMY SIGNAL CORPS*

CAPT. HALVOR T. DARRACOTT**

Through the Army Pictorial Service the Signal Corps serves as teacher, historian, and ambassador for the United States Army. Day by day demands for motion pictures of the combat zones, training films, film-strips, English versions of United Nations training films, special films for morale purposes are growing by leaps and bounds.

From a small group of officers and civilians and two training film production units, the Army Pictorial Service has grown into an organization including photographers spread throughout the world, as well as a major studio organization for the production of training films. The range of activities covered by this organization is decidedly comprehensive, including a good many contacts that are comparatively little known to the general public. The Army profits greatly by the thorough coöperation of the photographic and motion picture industries within the United States.

Proper operation of this far-flung Army Pictorial Service has been planned on a systematic and functional basis. The Army Pictorial Service has been set up as a separate service within the Office of the Chief Signal Officer. The Chief of the Army Pictorial Service also is a member of the Army Pictorial Board, which decides which organization within the three main divisions of our modern army—the Army Air Forces, the Army Service Forces, and the Army Ground Forces—will undertake the various photographic projects, and who will be responsible for their completion as well as for obtaining the necessary trained personnel to carry out those projects. Three branches make up the Army Pictorial Service: the Motion Picture Production Branch, the Pictorial Administrative Branch, and the Field Activities Branch. Each of these branches in turn has several sections, the numbers and functions of which are determined by the branch.

* Presented at the 1943 Spring Meeting at New York, N. Y.

** U. S. Army Pictorial Service, Washington, D. C.

The Motion Picture Production Branch is responsible for the procurement and production of all training films used by the three divisions of the Army. The Service concerned requests from the Chief of the Army Pictorial Service a training film on a particular subject. The project is set up, the "go ahead" signal is given, and the Motion Picture Production Branch decides whether or not the picture is to be produced commercially or by the Signal Corps facilities. In any event, by whichever method used, the film, in its final form, is viewed by the Chief of the Service concerned, and, when given his approval, is handed over to the Training Film Distribution Section for distribution and proper utilization within the three divisions of the Army.

The Motion Picture Production Branch also is responsible for the staff supervision of the procurement of film bulletins, film-strips, and special war films such as those being produced by the 834th Signal Photographic Detachment, which is showing the background, history, and effect of the present world conflict upon the conquered nations. Under the Special Projects Section films are produced at the rate of at least one per month for distribution to the war workers of the United States, who are shown how their particular jobs tie in with the war effort and what important parts they are playing in this conflict. Included in the Army Pictorial Service is the Combat Film Section, which is responsible for the assembling and distribution to the Bureau of Public Relations of the War Department of films exposed by the motion picture photographers of the Signal Corps in the combat zones. Film is received from the combat zones, developed, printed, viewed by the photo news board of the War Department, and classified according to its subject matter; and that which is permissible to be released to the general public is turned over to the Bureau of Public Relations for distribution to the newsreel services. This service is provided the newsreel companies on an exchange basis. Such footage as is shot in the combat zones by their own photographers as is needed by the Signal Corps for stock shots is turned over to the Signal Corps free of charge.

A special development laboratory unit known as the Signal Field Mobile Laboratory Unit has been organized to go into the theatre of operations and carry portable 35-mm development equipment. Taking the motion picture film exposed by the Signal Corps combat photographers in the theater of operations, this unit develops it and makes a print for the Commanding General and staff of that theater

to show the reaction of their troops to the present situation and how their work can be improved. Prints of these films will be returned to the United States to the Combat Film Section for distribution to the newsreel companies after classification, thus shortening the period between the time motion picture film is exposed in the combat zone and the time it is received in the United States for dissemination through the newsreel organizations.

The Field Activities Branch of the Army Pictorial Service contains the *V-Mail* Section, which is responsible for the utilization of microfilm to reduce to minute dimensions in bulk letters to and from our soldiers in the combat zones overseas, thus speeding up the news from the soldiers in the field to their loved ones at home or, from those at home to the soldiers on the firing line. Avoiding long delays of mail sent by other and less rapid means, this service contributes greatly to the morale of both the troops and those at home. The idea of this type of service originated in the Franco-Prussian War and was but recently revived. The modern system was first put into effect by Airgraphs, Ltd., which established microfilm letters for the British troops.

In May of 1942 the Signal Corps contracted for a similar service to be established for American troops under the name of *V-Mail*. Shipment of *V-Mail* letters in reduced or enlarged form is handled by the American Postal Service of the Adjutant General's office, while the reducing to microfilm and the subsequent enlargement to readable letters is done by personnel of the Signal Corps. Far-flung stations for the handling of the service have been set up in areas where American troops are stationed. Close coöperation is maintained by the Signal Corps with the British Airgraph Service, and arrangements have been made for *V-Mail* Service for the United States Navy and Marine Corps.

Signal Corps motion picture photographers use standard equipment, both 16- and 35-mm, and cameras of standard commercial design. The Army Pictorial Service has concentrated its efforts upon modifying the equipment, rather than designing new equipment to make it mobile and easily handled, and to simplify it in accordance with Army requirements. The Equipment Section of the Field Activities Branch has been responsible for the development and modification of standard motion picture cameras for use in the field.

The custodial responsibilities of the Army Pictorial Service are centered in the Still-Picture Section which has the celebrated motion

pictures and the still-picture file containing thousands of films shot during the First World War as well as famous collections of still photographers, such as Brady, of Civil War fame. Close coöperation with the United Nations Film Committee, especially with the British and Russian photographic Service, has resulted in the addition of a great many foreign training films in the stock of the Army. In return, American training films are being made available to others of the United Nations. Sound-tracks in the appropriate languages are added when necessary.

SOME PSYCHOLOGICAL FACTORS IN TRAINING FILMS*

COL. M. E. GILLETTE**

There are a number of purely psychological factors involved in making all types of motion pictures. Several of these, if properly recognized and utilized, prove to be powerful and useful tools in making training films. Five of the most important of these factors will be briefly discussed in this paper.

(1) The first is the "defect" in human vision known as the *persistence of vision*. This effect is responsible for our ability to see motion pictures. The eye retains the image of an object for approximately one-tenth of a second after the object has been removed. The removal and replacement of an image in the same position at a rate of more than ten times per second is seen by the eye as a single continuing image. In sound-films a series of twenty-four progressive images, or still pictures, per second flash upon the picture screen. When examined individually each of these twenty-four pictures is a "still" picture. If they are examined individually in a series, they show a progression of movement of the objects in gradually changing or advancing positions. When a series is projected upon the screen, it provides an illusion of motion. Use of this principle with lifeless objects or illustrations makes it possible to give an illusion of life and action to inanimate things.

(2) The second factor may well be termed "persistence of mental image" as distinguished from *persistence of vision*. Extensive use is made of this principle; in fact, it is the basis of story telling in all modern motion pictures. Motion pictures would be almost impossible or at least extremely unsatisfactory if producers were denied its use, as production costs would be prohibitive. It is the principle of connecting a number of scenes, photographed separately and at different times and places, into a continuity thus making it possible to tell a story. It is not widely understood outside motion picture fields, and even there the principle is not often expressed but is

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** U. S. Army Signal Corps Photographic Center, Astoria, Long Island, N. Y.

rather felt. It is used so widely and in so many different ways in film production that a full discussion of it would be beyond the scope of this paper.

For illustration, when a film producer wishes his audience to identify the action as taking place in New York City, he will flash upon the screen a general view of the skyline of lower Manhattan, a view of Brooklyn Bridge, The Empire State Building, Times Square, or some other well known landmark. Following this scene may come a view of some side street (a Hollywood replica, perhaps); then the front of a house (also a replica or a miniature); then the inside of a living room showing four persons sitting around a card table (a Hollywood studio scene); then a front view, medium close-up, of one of the players; and finally a close-up or an insert of the cards in the hands of a player—perhaps five aces! Individually, these scenes may have been made many miles apart, at different times, perhaps a year or more apart. Yet when presented in a film the aggregate mental image they create is the impression that the time is the present and that a man in a little house on a side street in New York holds five aces. Thus the director has created the background location and opening for his story, which persist until he wishes to change the locale by introducing another sequence of a similar nature.

In the entertainment film, *In Old Chicago*, extensive use was made of miniature and other camera trick devices. The general view of burning buildings from across the roof tops was a scene of a miniature town which had been set on fire. Street scenes were made outdoors on the studio lot. Views of the action inside the building were made on the studio stage; likewise, the close-up action of individuals standing against the sides of buildings were probably of studio origin. Examined individually in their local backgrounds, these scenes are not particularly impressive, but examined collectively after assembly by expert hands; they built an overall illusion of a major catastrophe, taking the audience into intimate details in such a manner that the audience did not feel any discontinuity or break in the overall action as the screen images rapidly shifted from exterior to interior close-ups, *etc.* The intermingling of scenes of miniatures and scenes of full-size figures and buildings was performed in such a manner as to obtain the overall illusion of reality, and the audience "saw" the people in the midst of the great fire. The persistence of the mental image established by the long shots carries through the showing of the close-ups and medium shots,

and, on the other hand, the mental images of the close-up action are carried over into the long views in the minds of the audience.

The interest-holding qualities and audience-participation in the midst of the action is wholly dependent upon the skillful use of this principle by the director and the film editors. In the motion picture industry scenes used to orient the audience as to where the action is taking place are known as *establishing shots*. This type of shot is very essential in instructional training films.

(3) The third factor is the principle of motion. A feeling of power results if an object starts at the center of the screen as a small image in the distance and rapidly approaches dead center on the screen until it finally fills the screen completely. When an object fills the screen initially and rapidly diminishes in size into the distance, a feeling of loss of power or relaxation results. Scenes photographed at a very low angle showing rapidly approaching action give a feeling of power.

A feeling of smoothness and continuing action can be obtained by using a series of scenes in which the movement is uniform and steady, and always in the same direction. The nearer the movement to the horizontal the greater is the effect.

An effect of greatly increased speed and excitement may result from action moving across the screen; the camera follows the action and the backgrounds appear to be moving. This is especially true of "pan" shots. For example, consider scenes showing a baby crawling, a man walking, a man on a bicycle, a man on a galloping horse, and a fast airplane. Arrange the scenes in the order named, starting with a fairly long scene of the baby crawling, and progressively shorten the length of each scene with the airplane scene the shortest in the series. The psychological effect is that of acceleration. Deceleration can be accomplished by the reversal of the example just given.

An object approaching diagonally down from a corner or the top of the screen will frequently produce the feeling that the action is taking place on a slope inclined toward the observer. This effect results from placing the camera high and tilting it downward. Likewise, an object coming from the bottom of the screen and moving upward frequently gives a feeling that the object is climbing a slope. When the camera is placed on the top of a hill and tilted downward, the action will appear to be taking place on level ground. Likewise, a camera placed at the bottom of a steep hill and tilted up-

ward will show the action as if occurring on level ground. At the top of the hill where the action disappears on the crest, it will appear to be moving down hill. A side position for the camera which profiles the action and the hill is the only position in which slope can be shown. In any position other than a profiling position, the camera definitely flattens the terrain.

A series of very short scenes or a composite scene showing action moving in many directions gives a feeling of confusion. Long scenes from the same viewpoint produce a reaction of impatience or slowness. Inadequate scene length in successive scenes produces a feeling of frustration due to the fact that the audience does not have an opportunity to understand what is occurring.

(4) The fourth psychological factor is atmosphere. The lighting of a scene—the brightness or lack of brightness, or the mood established through the placing of light, and the use of light and shadow differences in the scene—may create a definite reaction in an audience. In entertainment films, mystery pictures, for example, are usually photographed with low key lighting to assist in creating an illusion of mystery and the unknown. Comedies are generally photographed in high key; the scenes are bright and clear to assist in creating an illusion of lightness. Deep, murky shadows across a scene can be used to obtain a reaction of depression or suspense. A flat, muddy appearing scene made under rainy or dark light conditions gives a depression reaction.

Another factor is the environment or the surroundings of the center of action. Obviously, a refuse dump or paper-littered drill field has no place in the background of a film showing snappy drill. Incongruous backgrounds destroy the effect and validity of a scene. A shot simulating battle conditions made on the parade ground, for example, is greatly weakened if barracks show in the background. Likewise, a group of spectators or automobile traffic in the background will effect the same result.

Natural sound recordings can be used to supplement or reinforce the emotional reaction of a scene. When so used they become part of the "atmosphere" of the scene. On the other hand, incongruous sounds may seriously mar or destroy the desired effect or validity of a scene. Twittering birds, distant laughing, a train whistle, and similar sounds may mar the desired effect. The lowing of cattle at the instant a platoon leader commands "charge" will completely destroy the effect desired and turn a serious situation into a comedy.

(5) The fifth factor is the principle of comparison. In the entertainment field, in order to bring about the desired emotional effect, it is common practice to alternate pathos and comedy as relief mediums. In training film it is deadening and interest-destroying to hammer continually on "do this," "do that," *etc.*, without providing some means of relieving the tension of the audience. I do not, however, mean to infer that we should inject comedy or pathos as relief mediums into training films.

There are many ways of using this principle of comparison in the production of training films although they are not as obvious as the above examples. There are several methods of obtaining this relief without injecting irrelevant or distracting factors into a film. In a film that is basically a "what" or a "how" type of film, we are often able to inject a little of the "why" into the film to relieve tension and as an interest-arousing and a holding factor. The use of objects or ideas close to common experience may often be properly used to draw comparison and illustrate something otherwise abstract and thus relieve tension.

In films showing the duties of a gun crew in placing and serving the gun, relief can be provided by showing the result of such firing. In some types of films the nature of the action itself provides the necessary relief through the shifting of background situations or of action. While such relief is desirable and necessary, it is difficult to prescribe a definite formula as to its use, or to provide it without introducing undesirable factors. The use of this principle requires considerable thought during the planning and production stages, and wherever it can be used effectively with no undesirable results, it should be so used.

It may be safely said that sound-films can be used to arouse and influence all the human emotions, in practically the same way that similar real-life situations would influence an individual. The settings and lighting may depress or raise the spirits; movement on the screen may thrill or frighten; scene selection may transport us into distant lands or into the past. Any of our numerous emotions may be played upon by suitable scene action, scene selection, lighting, sound, *etc.* A complete discussion of these factors is impossible here. The examples mentioned should, however, indicate that this is a very broad and important field, and an understanding of the principles is necessary so that we may avoid introducing undesirable or unwanted reactions while striving to create those that are desirable.

TRAINING FILM PRODUCTION PROBLEMS*

LT. COL. R. P. PRESNEL**

In the Army, in the production of training films, we have a special phenomenon, and that is the making of motion pictures without artistic temperament. I think it is something new under the sun.

They say that war is a great leveller. You never hear an Army picture director raise his voice and shout or complain because everything is not exactly as he wishes it. Our camera units are also groups in which many sentences begin and end with the word *Sir*. We are fighting the war with scenarios, using words for ammunition. We have 90-mm adjectives, 155-mm verbs, 40-mm automatic nouns. And our theme song is, "Praise the Lord—and Parse the Ammunition." Our cameramen are mostly sergeants and our assistant directors are often corporals. They may carry gas masks and eat out of mess kits. They may drill mornings and nights to be ready. This is a new kind of motion picture making.

Training film production is the assembling of film into sequences that will teach military subjects to large audiences of average intelligence. All training films are aimed at the soldier in combat, or at least in the theater of operations, and are designed to teach him the use of his weapons, his equipment, the care of his health, and certain principles of tactics and individual care. For this reason, the close-up is used to the best advantage. In a sense the films are educational films, but with a different accent. The accent is speed and the ever-present reminder of danger. We have to put our message across with a sharp impact. That is one reason why we are in the Signal Corps: we have a message to deliver.

Most of the Army training films are made in the field, by which we mean camps and Army schools scattered throughout the country. In Astoria we have a large and excellent studio, an historic studio, of which we are very proud, but only a small percentage of our pictures

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** U. S. Army Signal Corps Photographic Center, Astoria, Long Island, N. Y.

can be taken indoors, on our stages. We can't maneuver tanks or lay down an artillery barrage, or stage cavalry movements anywhere but out in the desert, or range, or on practice grounds.

Our crews travel in camera trucks. We have done some experimenting in the building of these camera trucks, for compactness and economy of space, and camera equipment comes under the category of delicate instruments. The equipment must be carefully packed, cleaned, and cared for in the field so that it will continue to function. There are some fifteen or sixteen camera crews ranged across the country right now, and this represents a quarter of a million dollars worth of equipment that must be transported and taken care of. This is quite an item and quite a responsibility. It becomes even more complicated when sound equipment is added, all of which must also be transported and maintained.

We can not and do not send out great caravans to install set-ups for shooting outdoors. The average camera unit consists of five to seven men with an officer in charge. Officer, sergeant, privates, all bear responsibility. They must constantly improvise and meet the most unexpected events with American ingenuity, just as men in fox-holes and men in tanks are doing.

That is why we have no time for temperament. All have to work together. Working in the field, often under the most adverse conditions of weather and equipment, our camera units carry out the dictum of that famous general on Bataan: "We must make the most of the little we have."

I do not mean to imply that the Army does not give its crews the best equipment available, but rather that not too much is available anywhere these days, as you well know. A Signal Corps Camera Unit may be one in which a first cameraman—we do not have nearly enough of them—will also be his own operator and very often carry his own camera. Our directors do not have chairs with their names painted on them, and our script clerk very often is a utility man or assistant director to boot. He will take notes with one hand and carry a battery with the other.

In the field, our crews can not sit by waiting for the right weather or for light of exactly the correct quality. Colonel Gillette has given us a motto, "One training film on the screen today is worth ten on the screen next year." We have no time to lose—not a minute.

Our job is to teach men how best to protect themselves and carry out their duties in the face of peril. That means that photographic

excellence is not a prime consideration. And yet, we know that the best training films are those that are the best photographed and directed. If we want to teach other men to do their jobs well, we must demonstrate to them that we too are doing our jobs well. And, of course, we have a critical audience; our training film must compete for attention or admiring respect with the entertainment films that are shown nightly in the same camp. It may be said that what we have here is the problem of turning out pictures comparable in skill and finish with the best modern products of Hollywood, under conditions that in many ways compare to those that prevailed in the days of the motion picture's infancy.

This fact, that we are getting back to essentials in this work of ours, is perhaps the most outstanding. War is always a matter of getting back to essentials. So, in organizing our work and in training the men who are to make the training films, we have undergone a process of unlearning and reëducation for ourselves.

Many of the men in our units enjoyed reputation and success as writers and technicians in civilian life. They have come to us with complete knowledge of how to make pictures "the Hollywood way," but in the Army we are up against something different. The main idea in Hollywood technique is to entertain. When these same men write and shoot training films, their purpose is to teach. It is a different approach.

Obviously, the appeal of the training film is not to the emotions or even to the imagination, but to the mind. The training film must be written in simple language, so simple that any soldier may grasp its teaching. It must move quickly, yet must make its point very thoroughly without seeming repetitious. Men brought in to view these films may have spent hours marching or carrying out fatiguing duties. They may not always be as alert and attentive as they might otherwise be. The pictures may have to be shown more than once, and so they must not include scenes or speeches that on another showing will lose their original effect. For example, when we sought to lighten our films by the use of humor, we soon discovered that the jokes or gags did not "go over" very well the second time and third time. Similarly, suspense is not a very useful device for us. How to keep our films lively, how to bid for attention, and how to hold it, in the face of such restrictions—that is what our writers and directors are up against. How to climb a telephone pole, how to splice a wire, how to build a ponton bridge under fire, how to clean

a gun, how to avoid malaria, how to keep your feet clean—it does not sound like very interesting material, does it? But it is, and it is important that men know these things. Their lives depend upon it.

We give special orientation courses to our writers, designed to initiate them into the secrets of good teaching. We have lectures by psychologists who have studied the best methods and principles. It is not easy to stir or delight an audience with an exposition of how an anti-aircraft gun is put together. Yet that is a fundamental part of our job. We call such pictures “nut-and-bolt” pictures. Given the job of telling about the bolt mechanism of the *M-1* rifle, our writer has no opportunity to wax lyrical. But if the subject is thoroughly understood by the writer and is well organized by him, its exposition will be clear and interesting to the man who is to use the rifle and who appreciates how much depends upon his knowing how to fire it.

The scenario is especially important, and strict adherence to it is one of our production problems. We can not, as so often happens in Hollywood, rewrite our stories on the spot. We can not stop our shooting for story conferences. The branch of service for which we are working has given us a story, and we stick to it. That is because every line, every scene, every detail presented in our film has been carefully gone over and approved by experts. To make changes in the scenario would mean to go back through channels for approval. The fullest coöperation exists between the branches and us in the preparation of the scenarios—and we stick to the technical content because it represents the best thought of the Army on the subject.

Our writers travel to the service schools and often take courses in the subjects about which they are to write. They accompany troops on maneuvers, they watch experiments, they learn at firsthand, so that they can teach vividly and accurately. Technical advisers, men highly schooled in specific subjects, are always at hand. The writing of a training film is a matter of teamwork—hard, painstaking teamwork.

We thus observe our writers working side by side with military experts on poison gases, bombs, tanks, weapons of every kind. It has been one of the tasks of our writers, who speak the language of motion pictures in all its technical terms that sound so mysterious to outsiders, to put across their ideas to these men who are specialists in the various phases of military activity. We are frequently asked

to supply these technical advisers with a glossary of what is meant by "dolly shots," "pans," "wipes," and "dissolves."

Recently a military adviser suggested that a certain scenario submitted to him was, in his words, "pretty rugged," because he read so many directions calling for "shooting from the rear," "shooting from above," and thought we meant shooting with bullets rather than with film. He was considerably relieved when we explained that we did not intend to wipe out half the men assigned to us as actors. A very friendly and intelligent technical adviser not used to Hollywood talk, obligingly brought forth a T-square when the writer informed him that he would like another angle on a script.

We have succeeded, nonetheless. Indeed, sometimes we are so successful in winning over and educating these technical advisers in matters that have to do with the making of motion pictures, that we find ourselves with another problem on our hands: technical advisers succumb to the widespread temptation and wish to become motion picture producers themselves. This calls for the utmost tact on the part of those assigned to work with them for the temptation gets into the blood stream sometimes and the technical adviser becomes a very sick man.

In our films the organization of material is not our only problem. If Hollywood has a language of its own, so has the Army. We have had to learn how to speak Army language and also how to make Army language clear to our civilian soldiers. Much of the material we have put on film has already been set down in field manuals. The language of these manuals is very precise, but when read aloud it does not make the most interesting kind of narration. It "talks like a book." We have to tackle the job of translating this most formal and precise field manual language into everyday speech that will make the point more effectively and still be correct. Our films must be "racy" in speech and still have dignity, because they speak with the impersonal voice of the United States Army, whether our narrator is a tough old sergeant or a brigadier general.

The shooting of a training film is even more a matter of teamwork. It begins with preparations and explorations in which we try to foresee just what our crews will need or have to contend with from the moment they leave the post until the last foot of film is shot. It is like planning a campaign in miniature.

In order to obtain our actors, and, even more important, in order to obtain the military matériel—the tanks, the planes, the motor

vehicles, the guns, the jeeps, ammunition, chemicals—that we require when filming a picture, we must initiate requests through the appropriate channels. I need hardly tell you that we do not have idle tanks and idle guns and idle men standing around and waiting for us. Every gun, every tank, every man is busy; it is not easy for us to obtain their services, and when we do get them, we have to make efficient use of them without any loss of time. If we have been given use of a company of men today, we can not send them back because the sky is cloudy, and expect them on hand tomorrow. They may be scheduled for maneuvers tomorrow, and today's cast may be on its way overseas before the month is out. That means that if retakes are needed, that will not be a simple matter either. We have to shoot right the first time; the same rule that applies for the infantry man aiming his gun at the enemy applies to us also.

We have found it the best policy to use soldiers from the ranks as our actors, so that the men who see the pictures will most readily identify themselves with the men on the screen. We do not use the handsomest soldiers, or the trimmest, or the most stalwart or intelligent looking soldiers, but ordinary men of all racial types. We were considerably embarrassed, however, on one occasion, when one of the southwestern camps supplied us with a contingent of Japanese-American soldiers to enact an important scene. They were fine fellows and good soldiers and loyal to everything American, but we did not know how the rest of the Army would take instruction from them. It happened to be a scene in which poison gas was depicted, however, and so we were able to put them all in gas masks and get away with it. When these men had their masks on, we had no trouble with them in the matter of their stealing side glances toward the camera, but elsewhere we constantly have to work with camera-shy actors. Nevertheless, we think it worth while to use ordinary soldiers. These are pictures by soldiers, with soldiers, for soldiers.

It is not only the camera field units that have special problems. Our sound units have even greater difficulty, especially since planes are so likely to be flying over the camps where our films are being made. One director said to me, "If it isn't a plane, it's a train; and if it isn't a train, it's artillery on the range or target practice—and if it isn't target practice, it's crickets, and the damn crickets never stop!"

We have been short of such mobile sound units but their number has been increasing, and more and more we are being able to use

live sound to the heightened effectiveness of our film teaching.

This is a war of rapid change, of learning by experience. Procedures, weapons may change overnight, and we may find ourselves with a picture half finished and suddenly obsolete. Our films must be correct in every detail. We can not teach men methods that have been disapproved. You may be able to cover up a mistake in a historical picture in Hollywood. But we can not cover up anything. We must not make any mistakes. So we are frequently forced to very complicated expedients in order to save our films and keep them abreast of changes. We are in a race against time, but so is the whole Army, and we are only trying to keep up. The faster we make our pictures, the quicker our millions of men will be brought up to date in their training, ready for the task we all face.

Another aspect of our work is psychological preconditioning for battle. So far as possible, we try to simulate actual combat conditions and show the men that what they are learning in the camps will be applied in the moments of stress and crisis that await them. It is not the chief function of training films to be inspirational; they are not meant for propaganda, yet this element is not lacking altogether. We not only show men how to use weapons, but we suggest to them the urgency of their knowing how to conduct themselves properly with them. Among the training films we have made is a series for the Army Ground Forces in which various psychological problems that have to deal with fear in battle, and discipline, have been dramatically presented. I am proud to say that these films have won commendation from the War Department who told us that they considered them worth ten divisions to our Army.

THE SERVICE FILMS DIVISION OF THE SIGNAL CORPS PHOTOGRAPHIC CENTER*

LT. COL. EMANUEL COHEN**

The subject of this paper concerns a little known but rapidly expanding activity of the Signal Corps Photographic Center—the Service Films Division. The name *Service Films*, derived from the functional nature of the special films produced, best describes the type of motion pictures that are designed to provide a special service to the Army at large.

The Service Films Division was organized to consolidate all film activities which by their special nature could be classified as “service” and not “training” films. To distinguish between the two is difficult because it is hard to say that service films do not train, because they do; but their primary function is to disseminate information through the medium of motion pictures more effectively than through printed pamphlets and mimeographed letters.

Modern mechanized war changes so swiftly and new equipment is developed so rapidly that a film service equally as flexible was needed to transmit, visually, data on new weapons, equipment, and techniques to branches of the Army that could utilize the information to best advantage. Since training films are based upon doctrines developed over a long period of time, service films are designed to disseminate quickly new doctrines to Staff Officers whose task it is to evaluate every piece of new equipment and fighting technique and decide in the shortest possible time what equipment and methods are to be adopted by our fighting forces. Distribution of these service films is not limited to this country but is extended overseas for the information of officers and men in combat areas. Some service films show the various types, capabilities, and effectiveness of the enemy's weapons. Prints of this type of technical reel would be distributed to advanced echelons in combat zones as well as to ordnance officers in this country. By this means troops overseas,

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** U. S. Army Signal Corps Photographic Center, Astoria, Long Island, N. Y.

soon to face the enemy, are given a realistic demonstration of the latest types of weapons the enemy uses. Applying here the theory that he who is forewarned is forearmed, our officers and non-coms can use this information to devise defenses against these weapons and also to reduce the effect of shock encountered by troops who would have had to face a type of fire that they had no idea the enemy possessed.

For some time, high-ranking officers of the Army Ground Forces and the Army Service Forces had been considering ways and means of improving the use of chemical mortars—small cannons that fire smoke and other chemical shells. The officers were not satisfied with the number of men and pieces of equipment that were required to blanket an area with a smoke or gas screen. Numerous combinations were discussed pro and con and tested. Finally, the "Four-Point-Two Chemical Mortar," with its small complement of men and machines, looked most promising, so it was tested, not before a group of assembled staff officers on leave from their official duties, but before motion picture camera crews with their Eyemos and Mitchells which photographed every detail of the test far better than individuals could observe at firsthand with the naked eye. Not only was much time saved for a score or more of the Army's leading ordnance, chemical warfare, tactical, and other experts, but at the same time a permanent record was made that could be studied and restudied. This film also eliminated the necessity for restaging the tests at additional expense for those who could not attend because of the pressure of more important duties. As a result, the Army's eventual adoption of the Four-Point-Two Chemical Mortar was in no small part due to the film demonstration, which forms part of what is known as Film Bulletin No. 46.

Other bulletins and special productions made by the Service Films Division have included such subjects as "Battle Firing." This bulletin showed our men a new and revolutionary technique of firing small arms. To date a large number of analytical tests have been photographed for the various service boards of the Army such as the Ordnance Board at Aberdeen Proving Ground, where new types of American, allied, and enemy guns, bombs, armor-plate, jeeps, and trucks undergo continuous tests to develop the best arms and equipment for America's armed forces. Camera teams are stationed at these boards to make the tests when ordered. The commentaries of these bulletins stress the significance of the various scenes as they apply to training. Errors as well as proper procedure are pointed out in the narration.

Another activity of the Service Films Division is the Special Productions Branch. This unit makes special films ordered by, for example, the Secretary of War, who may request a film on the manpower resources of the United States; the Chief Signal Officer, who may wish to present a film report on the activities of the Signal Corps; or the Commanding General of the Army Service Forces, who may order a film made to demonstrate the huge supply problem involved in equipping and transporting America's first AEF to North Africa. These pictures are made within a given time limit, mostly from the extensive resources of the military stock film files of the War Department Central Film Library, also a branch of the Service Films Division.

The Central Film Library maintains a carefully edited file of some ten thousand cross-index cards describing the contents of more than two million feet of training films, film bulletins, special productions, film shot by the Signal Corps cameramen in combat areas, and miscellaneous military footage procured for use in official War Department pictures. These stock shots are used to expedite production, and represent the most extensive collection of indexed military subjects, edited and classified by specific types, available for immediate use. For example, if a piece of film were received by the library showing ninety-millimeter anti-aircraft guns firing at enemy planes in Tunisia, it would be indexed from a master editing sheet ("dope" sheet, which we make up upon viewing the film) as follows:

1. North Africa—Tunisia—Ninety Millimeter *AA* gun
ASF—Ordnance—Ninety Millimeter *AA* gun
AGF—*AA* Command—Ninety Millimeter *AA* gun
German—Air force—light bomber—Junkers Eighty-eight.

To summarize, the Service Films Division is comprised at present of branches that include the Film Bulletin Branch, which produces technical magazine reels of tests and demonstrations; the Special Productions Branch, which makes what the name implies; and the Central Film Library.

Plans have been made also for the expansion of the Service Films Division to include still further developments in the use of film to disseminate information jointly with other services, such as the Navy, Marines, and Coast Guard. As yet, no details can be given, but it will be an important step in the use of film in the War Effort.

ANIMATION IN TRAINING FILMS*

MAJOR ELLIS SMITH**

Animation is used in military training films when live-action photography is impracticable or impossible. Disturbing or distracting elements encountered in live action are eliminated, resulting in a clear, vivid portrayal unhampered by non-essential details.

Examples of the most frequent uses of animation are:

(1) Operating cross-section views of machine parts, such as the internal workings of guns, the movement of pistons and valves in internal combustion engines, the identification of parts, the interrelation of elements, and schematic chemical or physical processes.

(2) Tactical maneuvers covering large areas of terrain. Views from any altitude can be represented.

(3) Visualization of intangibles: gases, electricity, magnetism, molecular phenomena, thermodynamics, ballistics, microscopic activity, can be effectively demonstrated by animation.

(4) Animated graphs, charts, and maps permit simplified dynamic presentation of logistics, battle strategy, and personnel functions.

(5) Destruction of matériel can be shown by animation, thereby making it unnecessary to destroy actual equipment such as tanks, barrage balloons, buildings, aircraft, and ships.

(6) Live-action photography often can be clarified by superimposing dimension lines or captions, or by a combination of animation and miniature models.

(7) Accurate miniature working models are constructed and operated over miniature terrain in cases where natural locations are not available. This technique has been successfully used in training films concerning large truck convoys and the destruction of property by incendiary bombs.

(Applications of the various animation techniques listed above were illustrated by the projection of a number of scenes produced at the U. S. Army Signal Corps Photographic Center.)

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** U. S. Army Signal Corps Photographic Center, Astoria, Long Island, N. Y.

SOUND RECORDING AT THE SIGNAL CORPS PHOTOGRAPHIC CENTER*

MAJOR GARLAND C. MISENER**

Sound-recording operations of the Signal Corps Photographic Center are concerned principally with the production of army training films and special service films. Sound is used in training films very much the same as in commercial teaching films. Depending upon the type of subject and its treatment, some pictures are photographed silent, then scored with narration and essential effects; others are taken in live sound and augmented with effects and library music in the re-recording process.

Narration and live sound are cut into the picture by editors in the Editorial Branch. The picture is then turned over to the Sound Branch for music and effects editing. Commercial effects records are used to a limited extent. In most cases, however, authentic sound must be recorded, either wild or in synchronism, for in many cases the track is employed to demonstrate the characteristic sounds of weapons, control mechanisms, motor ailments, *etc.* The negatives of effects recorded specifically for a picture are catalogued in the effects library and stored for future use.

The Sound Branch embraces the following activities: field recording; recording of studio productions and narration score, domestic and foreign; music and effects editing; re-recording, domestic and foreign versions; installation and servicing of all sound-recording and projection equipment; practical instruction of combat unit personnel in sound recording.

The staff comprises both military and civilian personnel, including many experienced studio and newsreel men. However, due to the shortage of certain specialists, it has been necessary to make replacements and additions to our staff by selecting and training other men and women showing aptitude for sound production and equipment maintenance. The field recording units usually comprise one officer

* Presented at the 1943 Spring Meeting at New York, N. Y.

** U. S. Army Signal Corps Photographic Center, Astoria, Long Island, N. Y.

and three or four enlisted men. In the studio, the production day is divided into two eight-hour shifts, in order to realize the most efficient use of facilities.

EQUIPMENT

From a single sound and camera field unit of prewar days, the organization has undergone a manifold expansion, with a commensurate broadening of studio and field recording facilities. Field recording with portable channels was well under way at the time the base of operations was moved from Fort Monmouth to the Astoria studios in the spring of 1942. When the studios were occupied, two fixed channels of the original Paramount Western Electric installations were taken over, along with two film machines and one disk recorder. In addition, a new RCA re-recording channel was moved from Fort Monmouth.

The portable recording equipment consists of a group of RCA channels, purchased new and used as available. The older equipment includes two *PM-33* systems, one recording duplex track and the other modified to Class *A-B* push-pull variable area.¹ The film machines of the newer channels record Class *B* push-pull. The choice of Class *B* for original recording was based, first, upon a desire to eliminate ground-noise reduction equipment, with its heavy drain on the *B* supply, its relatively complicated adjustments and maintenance, and the unfavorable effects of its exposure control upon sound reproduction due to peak-clipping and ground-noise modulation. Moreover, the extended volume range of Class *B* not only accommodates more adequately original sound of great volume range, such as gunfire with its attendant breach and trajectory sounds, but it permits also recording at lower modulation levels speech and other sound in which overshooting produces objectionable distortion. The latter consideration is especially important when the recording channel does not include a compressor or volume limiter, as is the case with our present portable equipment.

One of the Class *B* channels, less the remote pick-up equipment, is shown in Fig. 1. The voltage and power amplifiers are mounted on an iron framework in a Fiberbilt case, with the carrying handles attached to the metal frame. Cable connections to this case, as well as to all other components of the channel, are made through Cannon *P*-type, six-pin connectors. Other fiber cases mount the recorder and carry the magazines, *B* batteries, and accessories. To

provide easier riding and to reduce vibration, Lord mountings have recently been installed on the recorder and amplifier cases. The recorder doors are being modified to incorporate red glass viewing windows, in order that the recordist may check by observation the film motion during takes.

Small, two-position mixers, which can be placed in any convenient location, are used in the field. The mixer panel includes a high-speed meter volume-indicator, a head-phone jack for the *MI-3456* high-

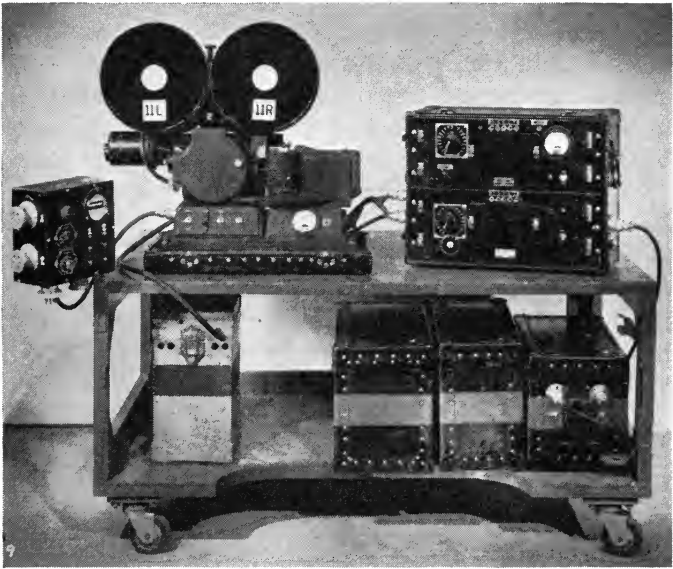


FIG. 1. Portable recording channel, with converter control panel.

fidelity head-set, a pair of dial lights and a preamplifier heater supply voltmeter and control. The volume indicator line is strapped to the recording bus, and the monitoring head-set is fed through a transformer bridging the "VI" line. The recordist monitors the same bus with crystal head-phones which plug into the recorder base. For intercommunication between the mixer and recordist, Signal Corps common battery field telephones are employed. The channel set-up is indicated in Fig. 2. Western Electric *618-A* and *630-A* microphones, the latter with baffles, are used in the field, while RCA *MI-3043-A* unidirectional microphones are generally used on studio pro-

ductions. Because of its light weight, the *630-A* is chosen for field work with duralumin fishpole booms. The feedback circuit of the microphone amplifier is adjusted for normal high-frequency film-loss equalization. The mixer circuit consists of two 250-ohm Daven volume controls paralleled through a fixed matching pad.

The main amplifier case mounts an *MI-10213* voltage amplifier, a low-pass filter, and an *MI-3233-C* bridging power amplifier. Adjustable dialog equalization has been provided in the form of variable resistance in parallel with an added interstage coupling capacitor in the power amplifier. A series of fixed resistors on the various positions of a rotary gang switch comprise the variable resistance, with the switch limited to screwdriver operation. The low-pass filter consists of a constant- k section and a shunt m -derived section in cascade, shunt-terminated and unbalanced, using air-core coils

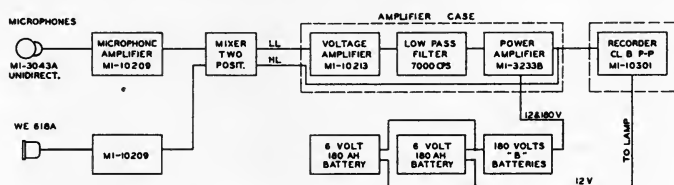


FIG. 2. Block schematic of portable channel.

wound in the sound shop. The case and transmission grounds are isolated up to the input of the power amplifier. This ground system, plus the radio frequency choke in the cathode circuit of the first stage of the preamplifier, minimizes radio and radar pick-up.

Plate and heater supply is brought to the main amplifier case through a single six-conductor cable, and is distributed to the pre-amplifiers through the low-level cable to the mixer. The portable channels operate on a standard cable-connection and impedance-matching arrangement which permits corresponding components, including recorders, to be readily interchanged. While the channels are ordinarily kept intact, this interchangeability is of prime importance in coping with emergencies and special situations.

The recorder is a *PR-22* type, with ultraviolet optical system, and is provided with interchangeable camera-type motors. The 220-volt synchronous motor is used on studio productions and in the field with battery-driven converters. Some units in the field use the d-c—*a-c* interlock system. The interlock motors are supplied

by a 120-volt bank of airplane batteries through a control panel at the recordist's position. The control panel mounts three motor-cable receptacles, individual field controls for each motor and a 48-cps Frahm frequency meter connected to the rotor circuit for monitoring the motor speed. The individual field controls permit compensation for differing motor loads, thus reducing any tendency to hunt.

Field units carry tungar battery chargers, and ordinarily have access to 110-volt a-c supply for charging batteries overnight. However, when companies work on locations remote from a-c supply, a standard Signal Corps gasoline-powered motor-generator set is carried for battery charging. The common 6-volt, 160-ampere-hour automotive type storage battery is being standardized for low-voltage supply. A Signal Corps extra-heavy-duty *B* Battery is employed for *B* supply in the field. For use with the portable channels in the studio, regulated *B* supplies have been constructed, employing standard cable connectors.

When using a portable channel on studio production, the recorder and main amplifier case are either set up on a double-deck dolly in a room just off the stage, or placed upon a bench in one of the basement film-machine rooms. For the latter arrangement, wall receptacles are provided for operating over the permanent *CTA* lines to the stages, and for d-c supply from rectifiers. Also available for studio use is one RCA *MI-3130-A* mobile stage console or "tea wagon," with a four-position mixer and adjustable dialog equalization.

The azimuth adjustments of the push-pull recorders, as well as the sensitometric conditions, are checked as regularly as possible by recording cross-over² and cross-modulation tests. Sound editing of the push-pull track is accomplished with the aid of moviolas modified for push-pull pick-up. This modification involves the mounting of a beam-splitter such as that used at Republic Studios. It consists simply of two small prisms mounted side by side immediately below the sound-track scanning point, deflecting the light transmitted by the two halves of the track directly onto the cathodes of a type 920 photocell. Azimuth adjusting screws have been added to the slit assembly to facilitate making the initial setting. The adjusting screws may be removed after the setting has been tied off with the clamping screws.

One Western Electric studio channel is used almost exclusively

for narration scoring, domestic and foreign, while the second is used on stage productions and scoring. The light-valves are biplanar, clamped-bridge type, worked with 0.5 mil ribbon spacing and white-light recording. The noise-reduction units have been modified for high-speed operation. Mobile stage consoles, built by Audio Productions, are used with the WE channels.³ These consoles include an adjustable dialog equalizer and an *RA-150* mixer amplifier. Through *CTA* lines, the *RA-150* feeds the bridging bus at the main

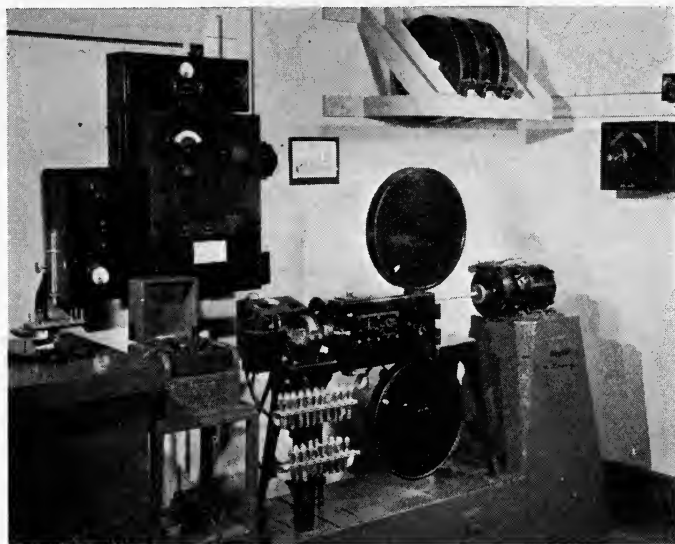


FIG. 3. Variable-density film machine with associated control panels and intercommunication devices.

amplifier rack. *D-86840* bridging amplifiers drive the valve and the *203-B* volume indicator, and supply the monitoring system with direct bridging bus monitor. Photoelectric-cell monitoring also is provided, with both monitors fed selectively into a *B-42-A* power amplifier which, in turn, feeds a *200-A* horn distribution panel. Each position on the *200-A* panel appears on a monitor-horn patch bay.

A Lansing Iconic two-way speaker system is employed in the monitoring room off the scoring stage, and 10-inch dynamic monitoring speakers are mounted on baffles at the film machine positions. Changing from direct to photoelectric-cell monitor is effected by

merely throwing a switch at the mixing console. The recordist is able to alternate between direct and PEC monitor at the film machine monitoring speaker, independently, by a simple change in patching on a rack near the machine. One of the recorder positions is shown in Fig. 3.

Intermodulation tests⁴ are recorded occasionally as a guide for determining and maintaining optimal sensitometric conditions, and the results are checked with listening tests on voice takes.

Foreign-version lip synchronous scoring is accomplished with the projection of loops of composite domestic prints for cuing. Port-

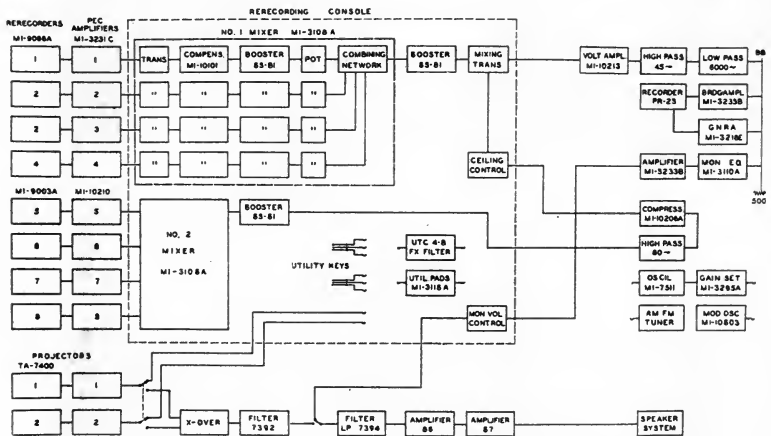


FIG. 4. Block schematic of No. 1 recording channel.

able loop stands accommodating any loop up to 80 feet are used. With the two projectors provided with loop stands, direct changeovers may be made, which makes it possible for the recording schedule to proceed without delays for threading. A third stand is available for use on loops exceeding 80 feet in length.

The Western Electric machines and associated cameras, as well as the machines of the re-recording channel, are operated from Western Electric interlock distributors, of which there are four. These distributors are powered by d-c drivers which are regulated by 700-A control panels. The four WE distributors, plus two smaller RCA distributors with synchronous drivers, appear on a central motor patch panel. The remote starting positions also appear on this panel permitting the control of any distributor to be patched to

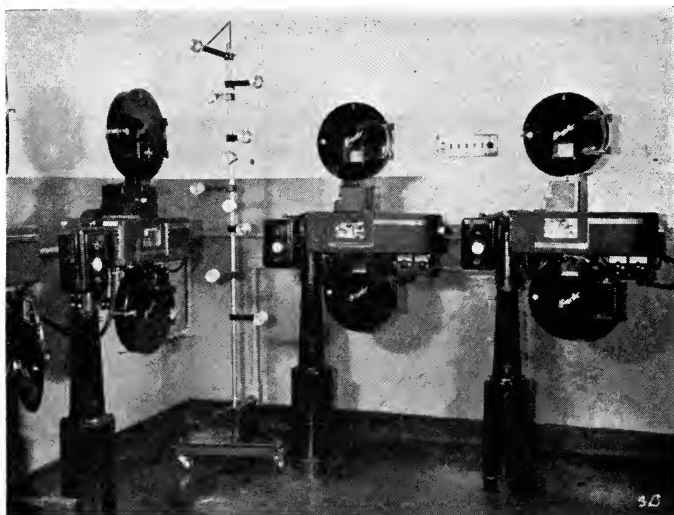


FIG. 5(a). MI-9666-A re-recorders.

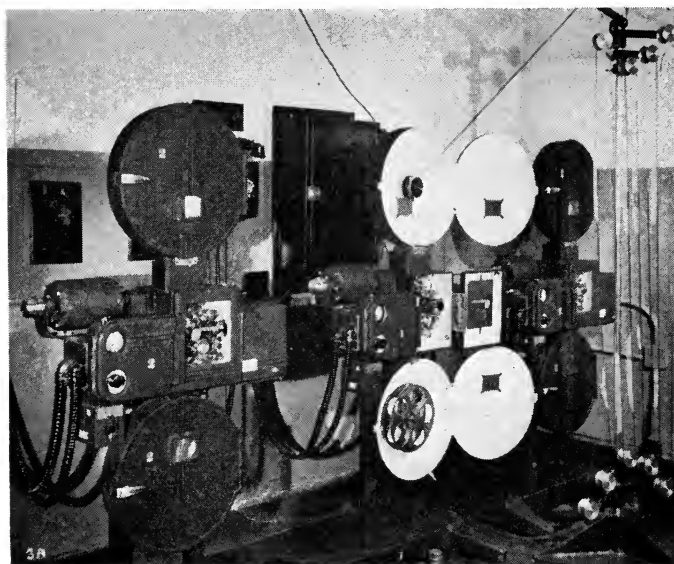


FIG. 5(b). Modified MI-9003-A Fantasound re-recorders.

any film machine, projection, or camera position. The RCA relay control boxes were modified by the addition of two relays, so that they also operate from the WE remote control positions, making all six distributors fully interchangeable in their application.

Mole Richardson type *103-B* microphone booms and perambulators are used on stage productions. Rubber suspension hangers are provided for all types of microphones, and tinsel adapter jumpers are used between the microphone and the cloth-covered



FIG. 6. Re-recording monitor room.

boom cable.³ Adapters have been made to accommodate the *630* microphone in the hanger for the *618*; this permits the use of either microphone with a spherical windscreen which fits into the *618* hanger. The booms are equipped also with gunning devices.

The re-recording channel layout is shown in Fig. 4. The four *MI-9066-A* re-recorders are theater-type heads, while the other four re-recorders are modified Fantasound heads, fitted with standard sound-head optical barrels, and using one of the four Fantasound push-pull beam-splitter assemblies.⁵ The eight re-recorders shown in Figs. 5(a) and 5(b), as well as the main amplifier racks and the *PR-23* recorder, are installed in a basement room. The re-recorders

feed two-stage PEC amplifiers, which are essentially modified portable microphone amplifiers, over 250-ohm lines. These amplifiers have approximately 45-db gain, as well as film-loss equalization; they are mounted interchangeably in slides on platforms at the rear of one of the equipment racks. To facilitate cross-patching, the sound-head outputs, as well as the PEC amplifier inputs and outputs and the trunks to the re-recording console, all appear on a patch bay.

The re-recording console and auxiliary film editors' tables were styled by Mr. R. Holley of RCA to meet certain requirements of this installation. The re-recording console, in relation to its position in the monitoring theater, is shown in Fig. 6. The face of the control board is illuminated by a rectangular spot projected from a spot mounted on the ceiling. At the base of the screen is a cabinet containing a model 301 volume-indicator and a footage counter, both of which are imaged on a translucent screen by rear projection. The counter is relay-operated, with switching accomplished by a commutator attached to the dubbing projector. A switch on the console operates the footage counter reset solenoid.

Fig. 7(a) shows the equipment layout on the mixing board of the console. There are two 4-position *MI-3108-A* re-recording mixers with a re-recorder trunk normaled to each input transformer. Normaled between the input transformers and the control pads of the No. 1 or left-hand mixer are *MI-10101* re-recording compensators and type *85-B1* one-stage booster amplifiers. These compensation units may be patched into any position of the No. 2 mixer as well. The output of each mixer is amplified with a type *85-B1* booster amplifier, and the booster outputs are combined in a mixing transformer which feeds the return trunk to the main amplifier rack. Appearing on the console patch bay is a compression section input and output; this section includes an 80-cps high-pass filter and an *MI-10206-A* compression amplifier mounted on the main amplifier racks, as well as a ceiling control at the console. This section is operated as a zero-gain device, and may be patched into the output of either 4-position mixer. Thus, the mixer is provided with considerable flexibility in the selective use of compression and compensation on the various tracks handled.

An *MI-3118-A* utility attenuator panel, a UTC Model 4-B effects filter, and two double-pole double-throw utility keys are mounted on the mixing board and appear on the patch bay. The volume-

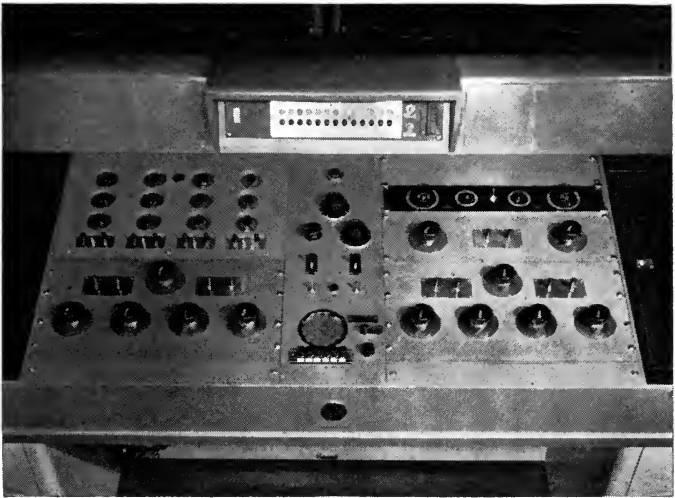


FIG. 7(a). Re-recording console mixing panels.

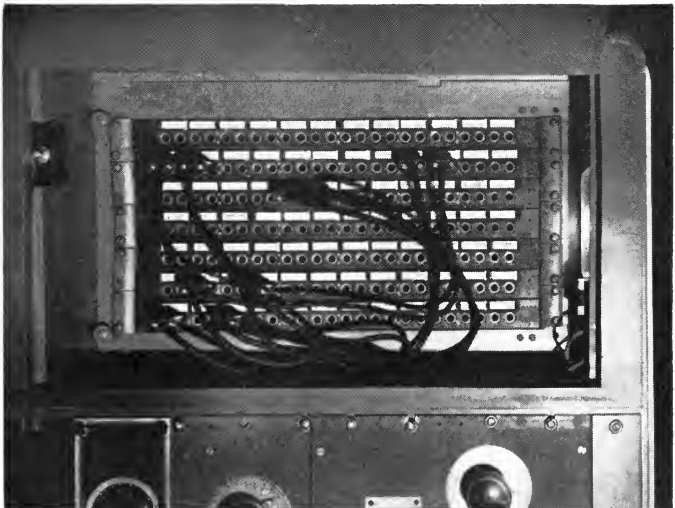


FIG. 7(b). Re-recording console patch bay.

indicator range switch, a talk-back intercommunication set, a signal-light switch, and a monitor volume-control also are mounted on the center panel of the console. At the top of the console, under the hood, is an *MI-3176* neon volume indicator,⁶ which may be used at the mixer's discretion.

In order to make the patch bay readily available to the mixer, and at the same time keep it out of sight and protected from dirt, it is recessed under a door at the top right side, as shown in Fig. 7(b). Illumination for patching is automatically switched on when the patch bay door is opened. The jack strips are mounted on a metal door which swings up on a hinge, affording convenient access to the jacks for servicing. All the *85-B1* amplifiers are mounted on a hinged rack inside the console in such manner as to afford convenient access to the terminal strips and tubes. An intradepartmental *PAX* telephone set and a telephone company set also are installed in convenient locations on the console.

The console output trunk is normaled to an *MI-10213* voltage amplifier on the main amplifier rack. This voltage amplifier is to be replaced by a second compression amplifier for volume limiting. Following the gain amplifier are a 45-cps high-pass filter and an *MI-3121-C* adjustable low-pass filter feeding the 500-ohm bridging bus. An *MI-3253-B* bridging amplifier drives the galvanometer, while an *MI-3218-E* ground-noise reduction amplifier, with logarithmic characteristic, actuates the ground-noise reduction shutters. An *MI-3110-A* monitoring decompensator also bridges the bus and feeds, through a monitor volume control on the console, the Western Electric sound system in the re-recording monitoring room. By turning a switch in the projection booth, the two *TA-7400* projector sound-heads appear on the patch bay of the console, which permits dubbing sound from composite prints.

A second re-recording channel is being installed in order to cope with the heavy production schedule.

Single-system sound cameras are used on newsreel type of coverage for special service films. The equipment consists of Wall cameras and RCA *PM-43* sound systems, recording Class *B* push-pull with ultraviolet exposure. A small 24-volt storage-battery unit provides the *A* supply and camera motor power. One man can carry the battery, amplifier, and accessory cases.

Greatly appreciated is the splendid coöperation given this organization by the equipment manufacturers in the installation and

servicing of the sound equipment. The excellent work of the military and civilian personnel of the South Branch is also cited.

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FIELD CAMERA PROBLEMS*

CAPT. R. L. RAMSEY

At the outset of the war our photographic facilities and equipment were called upon to fulfill the requirements of an all-out effort. It was necessary to get good effective training films into the training camps as soon as possible and it has only been through the steady and untiring efforts of all concerned that we have, in a relatively short time, been able to build up staff and equipment into a large working unit capable of turning out training films in quantity and of high quality. During the past year many problems have been encountered and investigated relative to the use of camera equipment for photographic training pictures.

While there is considerable research and preliminary work and thought required before a training film can be started, it is difficult to anticipate every demand that will be made upon the cameramen in the field. Many times it is necessary for cameramen to use their ingenuity in the field to obtain and record the desired scene action. It is not always easy, as the resources that are made available to regular studio workers are not at hand.

In many instances the type of work being shot is of such nature that it must be taken on a catch-as-catch-can basis, similar to newsreel work. Another important consideration that confronts photographers of training films is, "Does it Teach?" Unlike regular photography it is sometimes necessary to sacrifice pictorial quality for the purpose of emphasizing a training point. It is, however, necessary that the picture composition at all times be both pleasing and natural, while at the same time it is instructional. In this connection it has been necessary for many experienced cameramen coming into the Signal Corps Photographic Center to adopt new and revised methods of photographing scenes and to find ways of overcoming the obstacles that present themselves in the field.

As an example of such difficulties, Fig. 1 shows the conventional

* Presented at the 1943 Spring Meeting at New York, N. Y.

** U. S. Signal Corps Photographic Center, Astoria, Long Island, N. Y.



FIG. 1. Outdoor overhead parallel platform.



FIG. 2. Close-up of Fig. 1.

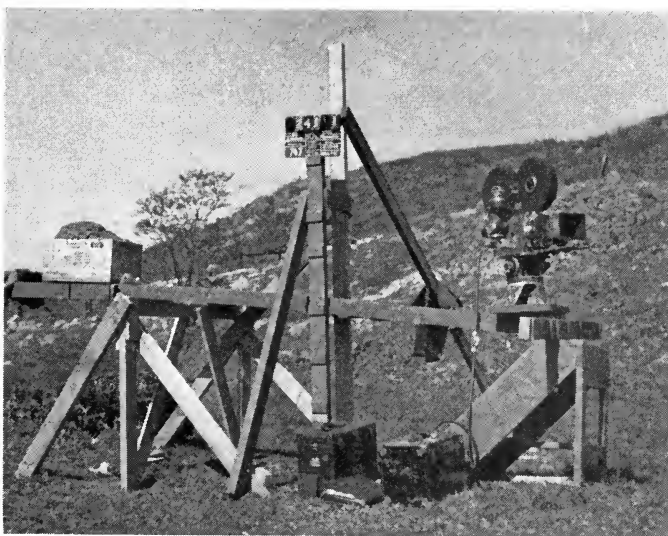


FIG. 3. A crude but practicable impromptu boom.



FIG. 4. Shooting under difficulties.

type of overhead parallel platform used in filming one of our recent training films. While this equipment is similar to what would be used in a regular commercial studio it shows that shooting training films in the field is not a one-man job. Many times it is necessary to have two or three cameras working on the same shot. Fig. 2 is a close-up of the same parallel assembly, showing the kind of set-up and camera equipment used. As can be seen, this is regular studio equipment.



FIG. 5. Shooting from a fox-hole.

Fig. 3 illustrates the ingenuity of some of the men. It was necessary to make a boom shot out in the field, and this crude but practical boom was constructed out of the available materials. While it was indeed crude, it did the job, which was the all-important thing since the work we do is measured against the time consumed.

Fig. 4 shows another kind of shot we are sometimes called upon to make. It illustrates a rather cramped shooting position for full-size camera equipment. In most instances there is not sufficient time or facilities for doing such photography inside the studio, where special lighting and equipment can be used. Here again, the camera-

man must use his ingenuity and take advantage of the available equipment to obtain the desired effect.

Fig. 5 shows an Eyemo Camera being used in a fox-hole with army trucks running overhead, and illustrates again the variety of equip-



FIG. 6. Trailer and jeep.

ment necessary for filming training pictures. It is often necessary to assemble equipment for short-order jobs, and locations for shooting are usually in remote parts of the country. For such assignments it is necessary to supply the crew with equipment suitable for any



FIG. 7. The contents of the trailer.

sort of photography they may encounter. With the benefit of past experience and a knowledge of the various difficulties encountered, we set forth to assemble an experimental mobile camera unit. The considerations confronting us are that the assembly of equip-



FIG. 8. Cameras in position.



FIG. 9. Mounting of the Mitchell, and the hydraulic pedestal.

ment should be compact, light in weight, readily mobile, and suitable for all kinds of photography.

Fig. 6 shows the trailer attached to the jeep which is used for conveying the entire outfit. We are all aware of the versatility of the jeep, and in designing the trailer we endeavored to make it just as practical. The trailer is equipped with electric hydraulic brakes and is completely protected against weather. It measures approximately $5 \times 6 \times 6$ ft, and weighs 2700 pounds when completely loaded.

Fig. 7 shows the contents of the trailer. A standard Mitchell camera is provided which can be mounted on a hydraulic pedestal, which is a permanent part of the jeep. The camera can be raised or lowered as necessary, and the usual gyro head serves all the purposes of a rigid mounting for stationary and mobile work. Tripods of various sizes are also provided for mounting the camera when it is to be used in the field. A 400-ft spider Eyemo is available, as is also a 100-ft model when it is necessary that hand-held shots be made. A 4×5 Speed Graphic still camera and complete accessories are also provided. Two broad-light units and one spotlight are included. The lighting equipment can be operated on regular electric supply lines, when available. A field-developing kit, reflectors, additional magazines, and all the other expendables required are also included.

Fig. 8 shows the outfit with two cameras mounted for photographing. The top of the trailer is flat, so we have the equivalent of an upright platform.

Fig. 9 shows the mounting of the Mitchell Camera and the hydraulic pedestal. This pedestal is an integral part of the jeep, rigidly mounted and reinforced for stationary or travelling shots. It is raised or lowered by the means of a foot-pedal at the base. An extension to the pedestal is provided if the camera needs to be raised beyond the limits of the hydraulic lift.

The illustrations may convey some idea of the kind of work being done. The jeep and trailer combination is purely an experimental assembly, but already many uses have been found for it.

MULTIPLE-FILM SCENE SELECTOR*

CAPT. HARRY W. LEASIM**

The Western Union Engineering Laboratories have just completed installation of five multiple-film scene selectors in The Pentagon, Washington, D. C. These units are used by the Army Pictorial Service in conjunction with the editing of motion picture films.

Prior to the installation of the mechanism, it was the custom to show the film to one person at a time. This person would actuate a buzzer whenever he saw a portion of the projected film he wished to have reprinted for his purpose. The operator in the projection room inserted a piece of paper into the take-up reel, and the process was called "papering" the film. Many hours were expended in this individual viewing of the same film as many representatives of various branches of the Army had to see the film to determine what parts, if any, would be reacquired by their respective organizations.

The director of Army Pictorial Service assigned qualified officers to find a solution of this problem. Knowing of several types of devices in satisfactory use by the Western Union Telegraph Company, a meeting was arranged with Mr. Dudley, Chief Engineer of the Western Union Company, and his assistant, Mr. Dirkes. The problem was discussed with them and several types of equipment were inspected with the point of view that any equipment that would require designing and retooling in manufacturing would not be desirable in view of the urgency of procuring the device. The Western Union Reperforators 10A were found to be satisfactory for the basic purpose.

Each perforated tape is capable of bearing five intelligence holes and one feed-hole, perforated transversely to the length of the tape at each tenth of an inch of tape. The reperforators are so arranged that each horizontal row of holes is associated with an editor so that on each perforated tape the requests of five editors will be recorded.

* Presented at the 1943 Spring Meeting at New York, N. Y.

** U. S. Army Pictorial Service, Washington, D. C.; deceased, June 24, 1943, while on duty in California.

The selection of film is made by the elimination of the associated horizontal row of perforated holes from the tape when the part of the film desired is being ordered.

The mechanism is arranged so that with the progression of one foot of film through the projector one transverse row of five holes will be perforated in the tape.

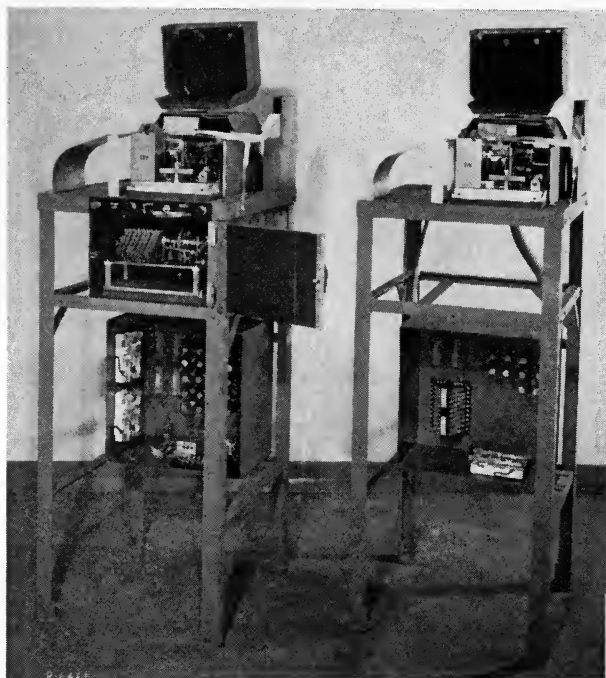


FIG. 1. Lead table (*left*) and auxiliary table (*right*).

The unit consists of a so-called lead table and a number of auxiliary tables, each of which records the requests of five editors. In the installation recently made, one of the sets consists of a lead table and three auxiliary tables, permitting twenty editors to register their requests. Four auxiliary tables can be added, and the number of editors increased to forty.

Each editor is provided with a switch and light unit at his writing desk position. As he watches the picture, he makes a request for

part of film by rocking a Levolver switch in the unit. A red lamp, also a part of the unit, glows, indicating that the request is being registered. When no more film is desired, the editor again rocks the switch and the light is put out, indicating that the request is ended. The mechanism is capable of registering requests for both 35 and 16-mm film.

The prepared tape, when ready for the cutting room, is run through a multiple film scene selector tape meter (Reader). The tape meter

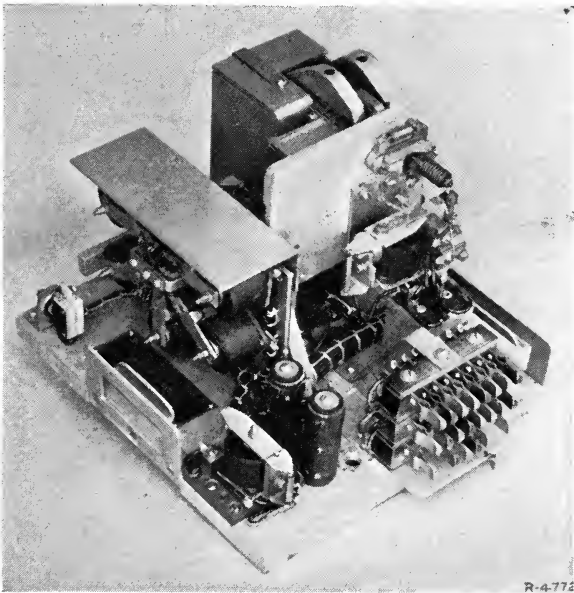


FIG. 2. Close-up of reperforator 10A.

counter is set to zero, and the tape is placed under the latch at the starting point. It is speedily fed through a tape transmitter until a request is encountered, whereupon one of a series of lamps is lighted, indicating in which row of holes a request is recorded and stopping the tape so that the operator may note the point in the film at which the request was made. The switch associated with the lamp is then thrown and the machine progresses until such time as another request is made or the initial request is ended, whereupon another lamp is lighted and another reading made.

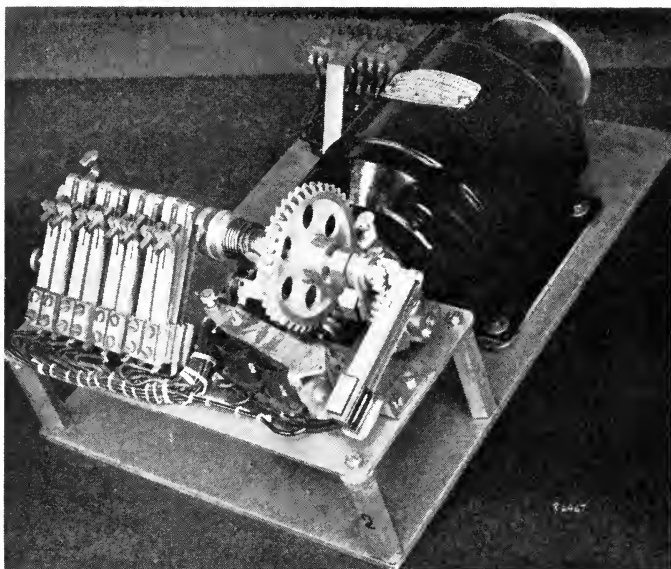


FIG. 3. Impulse unit 3A.

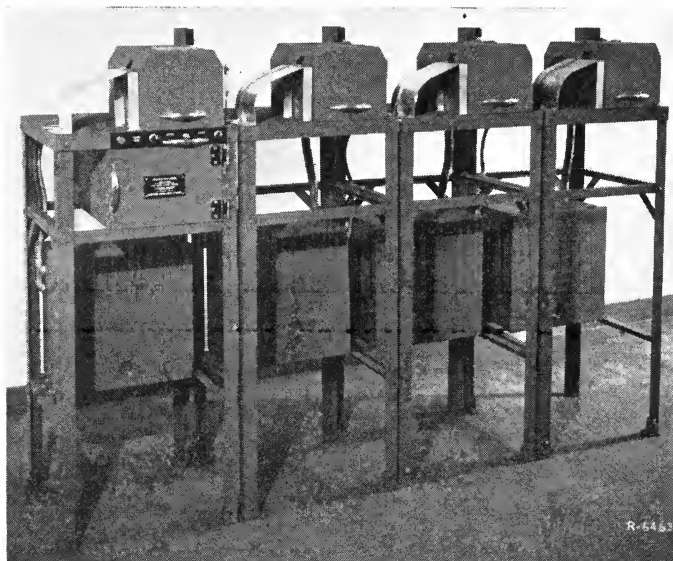


FIG. 4. Lead table and three auxiliary tables in the Pentagon Building installation.

Fig. 1. shows a lead table (*left*) and auxiliary table (*right*). The covers have been raised to show the mechanism. Fig. 2 is a close-up of Reperforator 10A and Fig. 3, the impulse unit 3A. Fig. 4 shows one lead table and three auxiliary tables installed in the auditorium in The Pentagon Building. Fig. 5 shows the tape meter.



FIG. 5. Tape meter.

The installation is now operating very satisfactorily. The multiple-film scene selector allows twenty representatives to review the film at the same time and provides for them access to the initial showing and selection of film so that the interested Services will have copies of films they desire without any loss of time.

FILM DISTRIBUTION*

LT. JAMES D. FINN**

It is certainly calling attention to the obvious to state that all the effort in planning and producing training films would be wasted without an efficient system of distribution that would put the films at the right places and at the right times for effective use. With millions of men in our Army scattered all over the continental United States and in many foreign theaters, efficient film distribution assumes the proportions of a tremendous problem in administration and supply.

After months of work, a new system of decentralized training film distribution has been worked out. It is the purpose of this paper to describe the functioning of the distribution of all United States Army films under this new decentralized system.

Since training films,* film-strips, film bulletins, and information films are not produced for theatrical entertainment, they can not be distributed on the same basis as theatrical films. Army films must be available at all times for showing to the men at any phase in the training period. The vital message of the films—a message that may mean the difference between life and death on the battlefield—must not be left to chance. Accordingly, it has been necessary to set up libraries of films and film-strips at all centers where troops are in training. These libraries act as the supply agencies.

For the administration and housekeeping purposes of the Army, there are nine Service Commands in the United States. The Commanding General of each of these Service Commands is responsible for all housekeeping and administration of the posts, camps, and stations within the several States comprising his command.

The basic unit of the Army film distribution system is the Central Distribution Library in the Headquarters of each Service Command. These Central Libraries have two distinct functions. One function is to supply films on loan to installations in the Service Command

* Presented at the 1943 Spring Meeting at New York, N. Y.

** U. S. Army Pictorial Service, Washington, D. C.

that are not large enough to have libraries. These installations include ROTC Departments, Ordnance bases, depots, and other small and isolated establishments. The second function of the Central Distribution Library is to act as a supply point for the various libraries at posts and camps.

The libraries at posts, camps, and stations within a Service Command are called sub-libraries. These libraries are divided into four classes, based upon the soldier population they serve. This classification of libraries *A*, *B*, *C*, and *D* exists mainly to control the amount of projection and library equipment issued.

Requests for additional prints of films for permanent retention are forwarded from the sub-libraries to the Central Distribution Library, and the orders are filled from stock. On initial distribution of new films, the Central Library makes recommendations to the Army Pictorial Service, and the prints are supplied direct in accordance with these recommendations. Sub-libraries may obtain prints on loan from the Central Libraries at any time, and, if the need arises, they may order prints for permanent retention.

In order to keep the Service Commands informed so that initial distribution recommendations may be made and acted upon without delay, the Army Pictorial Service furnishes information on the scope of the film and on the distribution recommended by the approving agencies.

This system has been evolved so that the right subjects get to the right places and little raw stock is wasted. The Service Command, for example, knows that the 1000th Cavalry is mechanized and has no use for such a title as the *Horse Gas Mask*, whereas if prints were distributed directly from Washington without these recommendations it might be possible that the *Horse Gas Mask* would end up on the shelf of a library serving tank units.

Some of the libraries within a Service Command are small and specialized and do not need to be included in any initial distribution. These libraries are called Auxiliary Libraries and are serviced from the Central Library or nearest sub-library. Only occasionally are prints required for permanent retention by these libraries. The designation of auxiliary libraries also prevents stock from being wasted and films from resting for months on library shelves.

The basic system of film distribution for Army training films then revolves around the library system. The nine Central Libraries, the sub-libraries, and auxiliary libraries stemming from them form a

distribution network that reaches out and touches the training of every soldier in the Army.

The American soldier, however, these days is wandering far from his native shores; and wherever large concentrations of men go, the film distribution system must follow them. Training takes place at overseas bases, and modern training requires films. Hence, a large number of overseas libraries have been created and are served directly by the Army Pictorial Service upon recommendation of the various Theater Commanders.

Another function of the distribution program involves the use of films not made by the Army. Films made by the British Government, for example, are sometimes adapted for use as U. S. Army training films and are distributed as such, but many others are made available to special Army installations on loan from the Army Pictorial Service. Films made by the United States Office of Education for the training of industrial workers have been converted where applicable and are distributed as training films.

Films made for the Special Service Division for orientation of the American soldier, such as the *Why We Fight* series, and films made for the Industrial Relations Division of the War Department Bureau of Public Relations for factory worker morale, are also distributed on a special basis. This latter type of distribution is operated on the familiar principles of theater booking.

Training-film distribution to Army Air Forces installations is not within the jurisdiction of the Army Pictorial Service. The Air Forces operate their own distribution system.

So far this paper has described the functioning of the general organization for the distribution of Army films. A great deal of detail work is involved which does not appear in this general description. For example, it was necessary to develop a booking system for the Central Distribution Libraries, and for the various sub-libraries, that would make the right film available at the right time for the using unit, and at the same time give enough information to make it possible to apply an inventory control.

This booking system is a combination system incorporating the best theatrical and non-theatrical practices, and certain new devices made necessary by the peculiarities of military organization.

Inventory control has been established in order to prevent use of unnecessary raw stock. Film stocks are checked by the Service Commands and reports are rendered monthly to the Army Pictorial

Service. By comparing stocks against booking and needs, it is possible for the Service Commands to re-allocate existing stocks and cut down the making of new prints.

TABLE I

Eighth Service Command—Extract of Report on Attendance

	December, 1942	January, 1943	February, 1943
Total number of bookings (all libraries)	13,396	14,886	20,159
Total number of screenings	19,993	25,819	26,919
Total attendance	2,284,997	3,550,853	3,745,465
Total number of previews held	136	315	341
Attendance at previews	3,959	6,944	4,507

The library reports serve also as a rough check on use, indicating by the number of showings and previews the extent to which available films are being used. Table I shows a tabulation of a portion of the report from the Eighth Service Command for a period of three months. It is obvious from a study of the total attendance figures that film use grows even over a short period of time. When we know that in the month of February, 1943, the attendance at film showings in the Eighth Service Command alone was 3,745,465, and that the message delivered at those showings will help toward success in battle, then we know that in a new way we are "Getting the Message Through."

FILM UTILIZATION*

BOYD T. WOLFF**

The utilization of films in the military training of our Army must be considered in the light of the tremendous job they have to do. Our films have to teach an Army to win a world; our films are for a student body of two million, five million, seven million, and more soldiers; our films are for a military training program in the greatest educational job we have ever undertaken—the establishment of a University of the American Army. Here is visual education on a scale that staggers the imagination of the most ardent instructional film enthusiast of prewar days.

This job calls for something different, something the makers of films have never done, something the users of films have never seen. It calls for a coördinated program of films complete from production to utilization. The training film program of our Army is, therefore, something new in visual instruction.

It is new in size, with more than 1000 titles, in 250 film libraries, for 7,000,000 men.

It is new in scope, with 25 different series, for every branch of the Service from Air Corps to Transportation Corps; with four different kinds of films (training films, film-strips, film bulletins, and information films) for four different needs (motion, stop-action, news, and history); and films adapted from United Nations pictures and from captured enemy pictures.

Producers, writers, directors, cameramen, technicians, actors, instructors, projection equipment experts are putting together their various skills in one unified set-up. Four major aspects of visual education—production, distribution, utilization, and evaluation—are bound together into a single organization, the Army, to achieve a common objective—training combat troops to be superior to the

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enemy. The purpose of this paper is to show how the Army utilizes films in military training, and what happens when the way films are used is considered as important as the kind of films used. One of the chief characteristics of Army films is that they are produced to fit specific objectives and to match definite plans prescribing their use in training.

Training Films are officially described as "sound motion pictures produced specifically for use as aids in expediting and standardizing instruction of the Army." Nearly all of them are available in both 16 and 35-mm size. "Each film follows the principles of accepted teaching method, is designed for showing before a particular audience group, and conforms in all details to approved War Department doctrine or technique."

Film-Strips are "series of still transparencies portrayed on individual consecutive frames of a strip of 35-mm motion picture film."

Film Bulletins "are designed to inform military personnel of current activities and developments in the war effort. It is desired that training officers employ these bulletins as an orientation medium and aids to instruction whenever possible."

Information Films are being produced as a new series under the general title, *Why We Fight*, to furnish military personnel with historical and general background information on the war. All these films are coming to reflect the global nature of the war as more and more are made from converted United Nations pictures and from films captured from the enemy.

Since these different types are produced not merely for variety's sake, the kind of job that each can do best must be clearly understood. Training films utilize to the fullest extent the element of movement. In dealing with any subject, the Army makes the most of showing possibilities ranging from minute workings of the smallest part to general operations over a large field. The utmost use is made of the camera's capacity to give a bird's-eye view or a microscopic close-up. The training film story may race through time or sweep over space, but always its prime purpose is showing people and things, individuals and parts, plans and events, *in action*.

Film-strips are utilized where the element of stop-action is of paramount importance. Where an arrangement of relationship needs longer study without consideration of movement, as in learning nomenclature, identification, construction, *etc.*, these are held in

view on the screen while the instructor comments as long as may be necessary. In this way the speed of showing is adjusted to the learning rate of the class.

Since basic technical principles of visual training and conditions for projection are common to all film aids, however, the term "training films" is used hereafter to mean any or all film aids except where specifically differentiated.

As to content and subject matter, both training films and film-strips are for specific training in military regulations, mechanics, techniques, and tactics in accordance with approved military doctrine. These comprise four groups arranged according to training plans to fit successive stages and specialized aspects of the soldier's instruction.

First the *basics*, required showing to recruits at Reception Centers. These pictures deal with first things first, take nothing for granted, leave no room for guesswork, introduce the new soldier to the Army. How must the enlisted man conduct himself? What is expected of him? He sees the film *Military Courtesy and Customs of the Service*. What are the rules and regulations that will govern his life in the Army? The *Articles of War* answers this question. What should he do if exposed to venereal disease? *Sex Hygiene* shows what to do and where to do it. Such matters are dealt with plainly. The first training films soon dispel any previous notions the recruit may have as to the effectiveness of old-wives' remedies or quacks' nostrum in dealing with the facts of life. Along with these he gets a glimpse of the fundamentals of soldiering, in a group of films that every enlisted man must see: *Identification of Aircraft, Adjustment and Inspection of Gas Masks, Map Reading, Anti-Mechanized Defense, Use of Natural Cover and Concealment, Weapons, Drill, First Aid, Safeguarding Military Information, etc.*

Second, third, and fourth groups of training films and film-strips are classed as *mechanical, technical, and tactical*, respectively. While they are not necessarily programed in that order, these are the films for advanced training of specialists. They are concerned with the structure, assembly, and disassembly of our own secret weapons, and the operation of vehicles.

The film bulletins cover experiments with, or trials and tests on, matériel, or methods that have not been accepted as official doctrine. They help the individual soldier see where his special function fits into the vast Army organization as a whole.

The information films are full-length features to give a broad

perspective of the war and the world in which it is being fought. These films are not intended to train the soldier in special techniques or knowledge, or to tell him directly how to do anything better; they are intended to enlist his sympathies and full emotional strength for fighting. They are to deepen and to extend his understanding of our cause. They are shaped primarily to get a response from his mind and heart rather than from his hands and body, to affect his attitudes rather than aptitudes; but in so doing, ultimately to make him a totally better fighting man. Information films produced so far are *Prelude to War*, *The Nazis Strike*, *Divide and Conquer*, and *Battle of Britain*. Pictures planned to round out the series are *The Battle of Russia*, *The Battle of China*, and *America in the War*.

None of these films is conceived as a substitute for the other. Each has the single message it can get across better than any of the others. It may happen that a training film, a film-strip, a film bulletin, and an information film may be on the same subject; but each represents a different approach, a different emphasis or treatment. For instance, on the subject of tanks, the training films *Armored Combat Vehicles*, *Armored Force Drill*, *Basic Tank Driving*, and *Advanced Tank Driving* deal with types of tanks and methods of using them, explaining their potentialities and limitations—long shots and close-ups in logical instructional sequence, with repetition and summary of important points. The film-strips *First Echelon Tank Maintenance*, *Tank Track Maintenance for the Light M3 and the Medium M3* and *Tank Inspection* cover common nomenclature, dimensions, details of construction and function, and diagrams of procedure, one step at a time. The film bulletins *U. S. Army Medium Tank M3*, *Tank Obstacles* and *Army Tank Destroyers* demonstrate trial methods of stopping tanks with obstacles, under severe testing conditions. The information film *The Nazis Strike* shows the kind of enemy tank action, in Czechoslovakia and Poland, that our troops must learn to combat. The Army instructor extracts the full value of each type of film aid by using it in planned relationship to the others and to his whole lesson. He sees to it that the manner in which the film treats the subject matches the way in which he intends to treat the lesson. He fits the film to the sequence of activities in training plans.

All these films are tools of instruction. They are source materials for a method of training, requiring their own method of specialized technique. They are vital weapons in the arsenal of

democracy. As such they demand just as much skill and understanding in their use as any other material of modern, mechanized warfare.

The first job of the Army instructor is to see that his men know how to look at films. He has to begin by explaining the difference between films "Produced by Military Authorities for Military Personnel for Military Objectives," and the kind of movies most of them are used to going to for amusement. He must explain why films are used in training and why there are different kinds of training films. The men have to learn the difference between really studying a film and merely watching it to see "How it comes out," for training films have to *take*. They must *stick*. They can not afford to be "filed or forgotten."

Among other things, the men have to learn how to observe a film selectively, systematically, and with concentration; how to take notes; how to ask significant questions. The instructor has to decide from his knowledge both of his subject and his men how many repeat showings are necessary and at which stages of the lesson they are needed. This varies as films vary between "basic" and "highly specialized technical" training films. It varies as men vary from those barely able to read to those with college training.

Training films are not presented as a short-cut to learning, or as necessarily easier than other methods. In no sense are training films frills. They are not meant to glamorize training. Our Army has a lot to learn in a little time, and training films teach more, in a clearer, faster way than any other means of instruction. As the largest group of potential learners in the world this unique film audience realizes it is there to learn the most serious lessons in the world.

To get this lesson across, the procedure for the most effective utilization of training films corresponds to the general sequence of steps outlined in the basic field manual on military training as follows:

The first step is *preparation*. Each film must be previewed by the instructor before showing. The instructor also must arrange in advance for booking the film and for the equipment, projectionist, and classroom. He must study correlative training literature.

The second step is *explanation*. Before each film showing the men are given a brief account of what the film is about and what they are expected to learn from it. They are informed that they will be quizzed on its contents.

The third is *demonstration*. This is the showing of the film itself. The instructor is responsible for setting up good screening conditions.

Before the filming he makes sure that the right film is ready, that the projector is set up and in working order, and that the screen is placed within the proper sight lines, without posts or other obstructions in the line of vision. He must arrange for maximum comfort of the audience and see that the room is ventilated and darkened to the extent of existent facilities; for it must be remembered that few of the projection rooms were designed for screening purposes.

The fourth is *application*. As often as possible the film lesson is applied in practice. It is recognized that vivid as a motion picture may be, it is one step removed from reality. The men are taken directly to such areas of activity as the drill field, the firing range, the shop, the convoy, the patrol, so that they may make the visualized experience their own through seeing, hearing, feeling, doing. Other visual aids such as models, sand tables, wall displays, still photographs, diagrams, charts, maps, *etc.*, related to the same subject are used as supplementary materials for study by individuals and small groups.

The fifth is *discussion*. Here also the men have a chance to participate. They ask and answer questions. In this phase of the instruction they show which things they learn quickly and which slowly, where their greatest difficulties lie and how the instructor can help them most.

The sixth and last step is *examination*. Following each screening the instructor asks fifteen questions which he has previously written on the film. A unique method has been worked out to simplify the administration of this quiz.

Each soldier is provided with a training film quiz card in duplicate. The card has two columns of fifteen tabs each—one column for answering "yes" and one column for answering "no." As each of the fifteen questions is asked, the student punches out the tab that he thinks gives the correct answer. When the questioning is ended he immediately hands to the instructor his duplicate card, with his name on it, and keeps the original as a record of his progress throughout the course. The instructor then reviews the quiz announcing or writing on the blackboard the correct answers so that each man will know his score before leaving the classroom.

The sequence of these steps may be varied to suit the circumstances and it makes no essential difference whether the whole procedure is

carried out during a single day or over a longer period of time. The instructor must know what he is going to do all the way through his cycle of instruction before he starts a course. He must take into account all possibilities. He must aim to use the film in such a way that without it something would be missing, and with it something is added that no other medium of instruction can supply.

Since training plans and schedules provide a "place for every film," every film must be used in its proper place—that is, only in connection with definite training objectives. These objectives are set by the highest training echelons which set up long-range schedules called Mobilization Training Programs for their accomplishment. Training programs that actually bring together soldiers, instructors, equipment, time, and place are worked out by division, regiment, and battalion training officers. Since all training films are designed for use in a larger plan, their full utilization is realized only when they are related to other coordinated activities of military training.

To expedite the use of training films in the field, the Film Distribution and Utilization Branch of the Army Pictorial Service provides the following services and publications:

Visual Aid Coördinators: for each of the nine Service Commands to give overall assistance on the spot where the films are actually used. As consultants and trouble shooters they bring all possible help from the War Department to assist in the installation of new film libraries and in the most effective use of films in training. What they find out in the field helps to bring about needed changes in procedure.

Basic Field Manual 21-7 gives a complete list of titles and brief notes on all training films, film-strips, and film bulletins. It is published twice a year.

War Department Training Circulars, with current information on Army Films, are printed monthly.

The Film Distribution and Utilization News Letter is issued in mimeographed form bimonthly with general reports on most recently approved and distributed films, and new developments in film utilization in the Service Commands and in the Army Pictorial Service.

Training Film Outlines for each training film produced.

Research Bulletins announce results of surveys on film utilization.

Standardized Quiz Answer Cards.

In summary, it should be remembered that training films, filmstrips, film bulletins, and information films are an integral part of the total military training program. They are not "extra added attractions" of military training. The Army has gone all out for visual training and it is bending every effort to see that the highest degree of skill in their use is developed. Films as matériel of war are one of the most potent of weapons in our arsenal of democracy.

It is hoped that the private industrialist who may be fearful that the government is taking over all film stock may take comfort in the fact that the way is being prepared for an educational film industry in peacetime such as never before has been conceived. It is hoped that the public, complaining perhaps of fewer new films at local theaters, will remember that there are more new films being made to help train our Army to save our lives.

FIFTY-FOURTH SEMI-ANNUAL TECHNICAL CONFERENCE

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

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There will be no special or prearranged ladies entertainment program during the five-day 1943 Fall Conference. However, a reception parlor will be available in the Hotel where the ladies may meet daily. The ladies are cordially invited to attend the functions of the Conference.

TENTATIVE PROGRAM**Monday, October 18th**9:30 a.m. *Hotel Lobby*; Registration.

The program for the morning of this date will be announced later.

12:30 p.m. *Terrace Room*; Informal Get-Together Luncheon for members, their guests, and families. The luncheon program will be announced later.

Due to the hotel labor and food situation, it is imperative members procure their luncheon and dinner-dance tickets at the time of registering so that the Arrangements Committee may provide the necessary accommodations.

2:00 p.m. *Blossom Room*; **General Session.**

8:00 p.m. **General Session**; the location will be announced later.

Tuesday, October 19th

10:00 a.m. *Hotel Lobby*; **Registration.** Open morning.

2:00 p.m. *Blossom Room*; **General Session.**

8:00 p.m. **General Session**; the location will be announced later.

Wednesday, October 20th

9:30 a.m. *Hotel Lobby*; **Registration.**

10:00 a.m. *Blossom Room*; **General Session.**

2:00 p.m. Open afternoon for recreational program to be announced later.

8:00 p.m. *Blossom Room*; **SMPE Fifty-Fourth Semi-Annual Dinner-Dance.**
The program for the evening will be announced later. (Dancing until 12:30 a.m.; strictly informal business dress and uniforms only.)

Thursday, October 21st

10:00 a.m. Open morning.

2:00 p.m. *Blossom Room*; **General Session.**

8:00 p.m. **General Session**; the location will be announced later.

Friday, October 22nd

10:00 a.m. *Blossom Room*; **General Session.**

2:00 p.m. *Blossom Room*; **General Session.**

8:00 p.m. *Blossom Room*; **General Session and Adjournment.**

Conference Headquarters

The Pacific Coast Section Officers have selected the Hollywood-Roosevelt Hotel, Hollywood, Calif., as headquarters for the 1943 Fall Technical Conference with the following *per diem* rates guaranteed by the hotel management.

Room with bath, one person.....	\$3.85
Room, double bed, with bath, two persons.....	5.50
Room, twin beds with bath, two persons.....	6.60
Small suite, parlor, bedroom with bath, single or double occupancy.....	8.80

Room reservation cards will be mailed to the membership early in September, and should be returned immediately to the Hotel. All booked accommodations will be guaranteed when confirmed by the Hotel Management. Reservations are subject to cancellation at any time prior to the Conference.

Indoor and outdoor parking facilities will be available at the Hotel headquarters if desired.

The Conference registration headquarters will be located in the Hotel Lobby, and members and guests will be expected to register and receive their badges and identification cards. The registration fees are used to help defray the Conference expenses, and coöperation in this respect will be greatly appreciated by the Local Arrangements Committee.

The identification cards will provide admittance to all sessions at and away from the Hotel. They will be honored also at the following *de luxe* motion picture theaters on Hollywood Boulevard, in the vicinity of the Hotel: Fox West Coast *Grauman's Chinese* and *Egyptian* Theaters, *Hollywood Paramount*, *Hollywood Pantages*, and *Warner's Hollywood Theater*.

Eastern and Mid-western members who are planning to attend the 1943 Fall Conference should consult their local railroad passenger agent regarding train schedules, available accommodations, rates, and stop-over privileges *en route*. If a San Francisco stop-over is included in the trip to the West Coast, the Conference Committee suggests the Mark Hopkins Hotel on "Nob Hill." Reservations should be mailed to Mr. R. E. Goldsworthy, Assistant Manager of the Mark Hopkins.

Note.—The 1943 Fall Technical Conference is subject to cancellation if later deemed advisable in the national interest.

W. C. KUNZMANN
Convention Vice-President

PAPERS PROGRAM OF THE FIFTY-FOURTH SEMI-ANNUAL TECHNICAL CONFERENCE

The Papers Program for the Fifty-Fourth Semi-Annual Technical Conference is progressing beyond expectations, considering the difficulties of the times. Although the arrangement of the sessions and the scheduling of the papers in the sessions have not yet been completed, the Papers Committee is pleased to present the following list of titles that will be included. Accompanying a number of the papers will be film presentations and demonstrations. The names of authors omitted from the following list will be given in the Tentative and Final Programs.

Some of the presentations will be given at the studios, and at least one or possibly two afternoons will be left free for diversion or other interests.

"Single Film Portable Recording Systems"; RCA Victor Division, Radio Corporation of America.

"Sound Installations in Washington"; RCA Victor Division, Radio Corporation of America.

"Acoustical Research Facilities at the RCA Princeton Laboratories"; Radio Corporation of America.

"New Duplex Loud Speaker"; J. B. Lansing, Altec-Lansing Corp., Hollywood, Calif.

"High-Quality Communication and Power Transformers"; Ercell B. Harrison, Altec-Lansing Corp., Hollywood, Calif.

"250-Watt Class-B Audio Amplifier"; John W. Hilliard, Altec-Lansing Corp., Hollywood, Calif.

"Post-War Television Planning and Requirements"; Klaus Landsberg, Television Productions, Paramount Studios, Hollywood, Calif.

- "A Simplified Variable-Density Sound Developer"; Paul Zoff and F. J. Twining, Columbia Pictures Corp., Hollywood, Calif.
- "Walt Disney Studio—a War Plant"; Carl Nater, Walt Disney Studios, Burbank, Calif.
- "Present and Proposed Use of Plastics in the Motion Picture Industry"; Barton H. Thompson, Paramount Pictures, Inc., Hollywood, Calif.
- "Sixteen-Mm Color to 35-Mm Black-and-White"; Carroll H. Dunning, Dunning Process Co., Hollywood, Calif.
- "The Future of the 16-Mm Sound-Film Industry"; John A. Maurer, J. A. Maurer, Inc., New York, N. Y.
- "What to Expect of Direct 16-Mm"; Lloyd Thompson, The Calvin Company, Kansas City, Mo.
- "Improvements in Sound Recording Equipment"; L. F. Brown, ERPI Division of the Western Electric Company, Hollywood, Calif.
- "A New Sound Reproducer"; ERPI Division of the Western Electric Company, Hollywood, Calif.
- "A New Single-Film Recording Camera"; George Worrall, Mitchell Camera Company, Hollywood, Calif.
- "Duplication of Kodachrome Original, with Enlargements, Reduction, and Color Correction"; Earl Morgan and Roy Peck, Paramount Pictures, Inc., Hollywood, Calif.
- "Transfer of Kodachrome Emulsion to Lantern-Slide Glass"; Barton H. Thompson, Paramount Pictures, Inc., Hollywood, Calif.
- "High-Efficiency Stereopticon Projection for Color Background Shots"; A. C. Zoulis and Farciot Edouart, Paramount Pictures, Inc., Hollywood, Calif.
- "A 200-Mil Push-Pull Sound-Recording System"; L. D. Grignon and J. P. Corcoran, Twentieth Century-Fox Film Corp., Hollywood, Calif.
- "A Visual Light-Valve Checking Device"; J. P. Corcoran, Twentieth Century-Fox Film Corp., Hollywood, Calif.
- "Improvements in the Disney Scoring Stage"; C. O. Slyfield, Walt Disney Productions, Burbank, Calif.
- "Improvements in the Columbia Scoring Stage"; J. Livadary, Columbia Pictures Corp., Hollywood, Calif.
- "New Scoring Stage, Shell, and Vocal Booth Design"; Loren L. Ryder, Paramount Pictures, Inc., Hollywood, Calif.
- "Combination 16-Mm Contact and Optical Printer"; Irving B. Dyatt, Oregon State College.
- "A High-Speed Method of Controlling Kelvin and Light Intensity for Motion Picture Printers"; Irving B. Dyatt, Oregon State College.
- "Modern Processes of Color Photography"; Joseph S. Friedman.
- "Cunningham Combat Camera"; Harry Cunningham, RKO Studies, Hollywood, Calif., and Capt. E. H. Fehnders, U. S. Army Signal Corps.
- "Improvements in 16-Mm Equipment"; Commander Alfred Gilks, Office of Strategic Supplies, Field Photographic Branch.
- "The Work of the Training Film Branch, Photographic Division, Bureau of Aeronautics, U. S. Navy"; Lt. Orville Goldner, U. S. N. R., Washington, D. C.
- "Production Planning for Navy Training Films"; Lt. R. B. Lewis.

"Making Films That Teach"; Lt. Reginald Bell, Training Film Branch, Bureau of Aeronautics, U. S. Navy.

"The Training Film Program in Action"; Training Film Branch, Fire Control School, Navy Yard, Washington, D. C.

IMPORTANT

Hotel reservation cards must be returned immediately. Otherwise the Hotel cannot guarantee accommodations.

Members intending to attend the Fifty-Fourth Semi-Annual Conference should make arrangements for their railroad accommodations immediately or at the latest one and a half months in advance of the Conference date.

SOCIETY ANNOUNCEMENTS

AMENDMENTS OF THE BY-LAWS

At the meeting of the Board of Governors held at Hollywood on June 4th the following proposed amendments of the By-Laws were approved for submittal to the membership of the Society for voting at the Fifty-Fourth Semi-Annual Technical Conference, to be held at Hollywood October 18th to 22nd, inclusive.

Proposed Amendment of By-Law IV, Sec. 4(b)

To the list of standing Committees appointed by the Engineering Vice-President shall be added the *Committee on Test-Film Quality*.

Proposed Amendment of By-Law IV, Sec. 5

Two Admissions Committees, one for the Atlantic Coast Section 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, residing in the metropolitan area of New York, of whom at least 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 residing in the Pacific Coast area, of whom at least three shall be members of the Board of Governors.

MAILING OF NOTICES TO MEMBERS OF THE ATLANTIC COAST SECTION

As the territory included by the Atlantic Coast Section of the Society extends from Maine to Florida and includes the Eastern and Central Standard Time zones (as the result of the discontinuance of the Mid-West Section), many of the members of the Section find it impossible to attend the monthly meetings and other functions. The situation has been considerably aggravated by the present difficulties of transportation.

For these reasons, as well as for reasons of economy, the Board of Governors, at the meeting held on May 3rd at New York, felt that notices of meetings, routine letters, and other material should be sent only to members of the Section residing in the New York metropolitan area, since it is from this area that the meetings draw practically all their attendance.

However, the Board provided also that members not residing in the New York metropolitan area but who wish to receive such notices, *etc.*, may have their names continued upon the mailing list of the Section by writing to the office of the Society, at the Hotel Pennsylvania, New York, N. Y.

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 (not 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. Sound-Film

Approximately 500 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 10,000 cps.; the constant-amplitude frequencies are in 15 steps from 50 cps. to 10,000 cps. Price \$37.50 each.

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.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

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

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

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Frank H. Richardson

As the October Journal goes to press we learn with sorrow of the death of Frank H. Richardson, Fellow of the Society and a member since its founding in 1916. We have lost a loyal and active associate whose devoted interest in the welfare of the Society will long be remembered.

The Society of Motion Picture Engineers

Its Aims and Accomplishments

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

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

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

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

THE GENERAL ELECTRIC TELEVISION FILM PROJECTOR*

ELLSWORTH D. COOK**

Summary.—In the following paper, the General Electric television motion picture film projector is described by its designer. Certain of the design objectives and some of the special problems involved are discussed. Among these problems is the projection of standard motion picture film at thirty television frames per second without change in sound quality. The theory and construction of the intermittent movement are given and views are shown of the projection equipment as installed in the General Electric Television Station WRGB.

Because of the great amount of time necessary for the rehearsal of each new act, the rapid exhaustion of available subject material, and the general interest in news events, it is thought that much of the subject material for commercial television programs will be obtained from current motion picture films as soon as widespread use is made of this facility.

The operational standards chosen for television have made it necessary to redesign or modify existing motion picture projection equipment, at least at the beginning of television broadcasting. This condition is likely to continue since it does not seem practical to finance "retakes" of the desired subject material or that motion picture producers would be willing to revise their equipment to fit new standards, particularly since they have just passed through one such major and expensive revision in connection with sound recording.

The present standard television picture is formed by an elementary spot of light of varying brilliancy moving across the picture frame in parallel lines. Since there are 525 approximately horizontal lines for each television picture, and since the picture is formed by first traversing the odd-numbered lines and then the intermediate even-numbered lines, it is evident that the detail of the picture would suffer if, for any reason, these alternate lines should overlap. It

* Presented at the 1942 Spring Meeting at Hollywood, Calif.

** General Engineering Laboratory of the General Electric Company, Schenectady, N. Y.

has been thought that the limit of any displacement between the alternate lines should be equal to one-half of their relative spacing. Thus, a vertical displacement of approximately $\frac{1}{10}$ of one per cent would represent a practical, superior limit for any such motion. Since, as will be seen later, the odd-numbered lines of certain definite, television pictures may be obtained from one individual frame or picture of a motion picture film, while the even-numbered lines may be obtained from the following frame, it will be evident that a logical specification for the accuracy of registration of succeeding pictures thrown upon the reproducing screen by the motion picture projector would be this same figure, $\frac{1}{10}$ of one per cent, as an upper limit. Naturally, such a specification would assume that equal accuracy will be found throughout the entire television system responsible for the line structure, as well as in the motion picture camera and printer, and that a proper film, once made, could be maintained if such performance is to be effectively employed.

A careful consideration of the requirements for speed constancy and experience with the possibilities of the better forms of mechanical filters in this field reveal that in the matter of construction to meet the desired specification, the advantages should lie with the intermittent type of projector rather than with the so-called "continuous motion projector." In fact, the problem of film shrinkage alone would be sufficient to cause the experienced designer to prefer the former type of machine.

This paper is a description of the G-E standard 35-mm motion picture projector development for television service. This project was started in March, 1938, and two of the projectors described have been in use since December of that year. Because of its design, the *E-7 Simplex Projector* was chosen and modified to suit the special conditions peculiar to this field. The operating side of the projector is shown in Fig. 1.

It has been standard practice in television to use a frame frequency which is a sub-multiple of the frequency of the supply voltage, for instance, 30 per second, because of any possible residual hum in rectified d-c voltage supplies. The present standard sound motion picture practice utilizes a frame frequency of 24 per second. In order to bring these two standards into agreement so that standard sound motion picture film may be used, it is necessary to employ a varying frequency of projection so that the average frequency may remain 24 film frames per second. This is possible if the *instantaneous*

projection speed alternates between 30 and 20 frames per second in such a manner that the average film speed may remain 24 frames per second.

Since the slower instantaneous projection frequency would leave a given film frame in the projection aperture for a time interval that would be fifty per cent greater than that for the higher projection

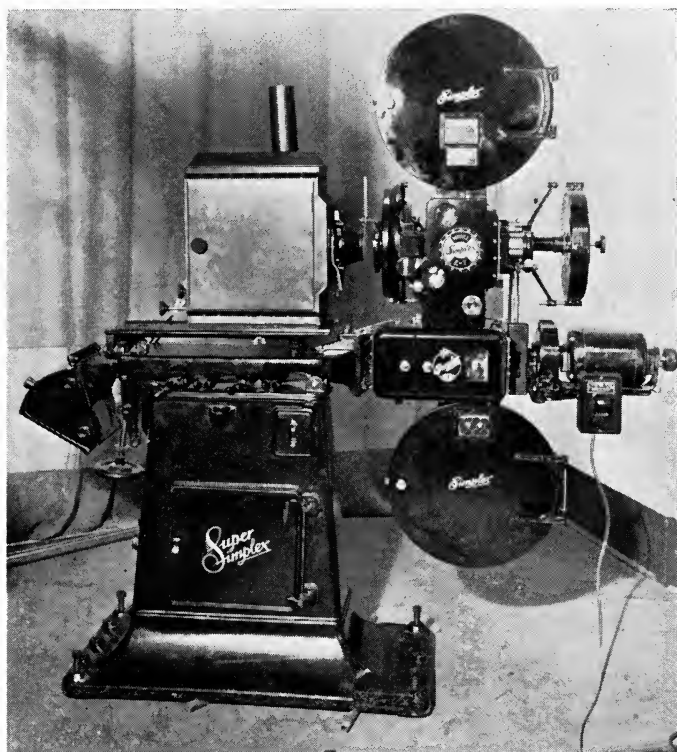


FIG. 1. The General Electric television motion picture film projector.

frequency, it will be evident that any mechanical movement, which will project *two film frames* for each complete revolution of its drive shaft in such a manner that each film frame will remain in the projection aperture the necessary length of time and one will remain fifty per cent longer than the following film frame, may be used for this purpose. This may be easily understood by reference to Fig. 2

which shows the time cycle of events in the standard motion picture sound-film and the same film as used in television.

It will be essential that the drive shaft to the intermittent movement in question rotate at the same speed that an otherwise standard motion picture device would be forced to use to project two

NUMBER OF FILM FRAME	STANDARD SOUND FILM CYCLE	ELAPSED TIME IN SECONDS	NUMBER OF TELEVISION FRAME	TELEVISION CYCLE FOR STANDARD FILM WITH 7.5% ILLUMINATION TIME	ELAPSED TIME IN SECONDS
1	ILLUM.	.0104	1	ILLUM.	.0000
	DARK			DARK & SCAN	.0013
	ILLUM.	.0208		ILLUM.	.0167
	DARK & MOVE	.0313		DARK & SCAN & MOVE 1 FILM FRAME	.0179
2	ILLUM.	.0417	2	ILLUM.	.0333
	DARK			DARK & SCAN	.0346
	ILLUM.	.0521		ILLUM.	.0500
	DARK & MOVE	.0625		DARK & SCAN	.0513
3	ILLUM.	.0729	3	ILLUM.	.0667
	DARK			DARK & SCAN & MOVE 1 FILM FRAME	.0679
	ILLUM.	.0833		ILLUM.	.0833
	DARK & MOVE	.0938		DARK & SCAN	.0846
4	ILLUM.	.1042	4	ILLUM.	.1000
	DARK			DARK & SCAN & MOVE 1 FILM FRAME	.1013
	ILLUM.	.1146		ILLUM.	.1167
	DARK & MOVE	.1250		DARK & SCAN	.1179
5	ILLUM.	.1354	5	ILLUM.	.1333
	DARK			DARK & SCAN	.1346
	ILLUM.	.1458		ILLUM.	.1500
	DARK & MOVE	.1563		DARK & SCAN & MOVE 1 FILM FRAME	.1513
		.1667			.1667

FIG. 2. Time cycle comparison for motion picture film in television and theater projectors.

film frames per revolution of the equivalent shaft. In the usual projector (and this applies to the standard model *E-7* used here) only one frame is projected per revolution. Hence, this drive shaft normally revolves at 1440 rpm.

In the design of the modified machine, this would call for the inter-

mittent drive shaft to operate at a steady speed of 720 rpm with projection occurring at a reference point and again 144 degrees later for each revolution; *i. e.*, each revolution is divided into parts respectively of $\frac{2}{5}$ and $\frac{3}{5}$ in duration. Such a design would produce a severe screen flicker and if this is to be avoided, the number of pictures projected per second would have to be increased. This may be accomplished if the viewing time of such a sequence of operations is interrupted, as in standard motion picture operation.

If two views of the same picture are to be seen during the $\frac{2}{5}$ portion of the cycle, three views of the next film frame will be seen during the remaining $\frac{3}{5}$ portion of the cycle. Therefore, it is obvious that the intermittent film motion could not be permitted to utilize 90 mechanical degrees of the intermittent drive shaft rotation. This is important, since it rules out the standard form of Geneva motion.

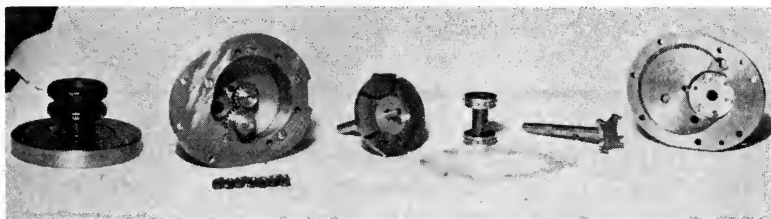


FIG. 3. Disassembled view of intermittent in General Electric television projector.

It was mentioned previously that in present television practice in the United States, which practically presupposes the use of cathode ray tubes, the picture is "painted" by a flying spot of light of varying intensity that moves across the field in approximately horizontal lines, and that each of the successive elementary pictures is composed of the alternate lines, respectively. This succession of events occurs in such a way that these elementary pictures follow one another at a rate of 60 per second, being interlaced with a maximum time interval of eight per cent between them, according to the present standards. It is within this short time interval that the film will be illuminated, and if a blurred picture is to be avoided, the film must be at rest during the period of illumination.

Thus, the complete operation for each individual or elementary television picture must be confined to 72 degrees of mechanical rotation of the intermittent drive shaft, while the motion of the film

at the projection aperture must be completed in 66.24 degrees of rotation of this same shaft, if the projector is to be synchronized with the flying spot. One of the simplest movements known that can operate with this reduced angle of motion and give a high degree of registration, is the Powers movement. This is essentially a face cam. The intermittent sprocket shaft terminates in a plate with four pins located on a square so that two slide on the outer cam surface and two slide on the inner cam surface. A disassembled view of the intermittent movement may be seen in Fig. 3. The principle is covered by the patent issued to A. V. Bedford (U. S. 2,082,093).

It is noted that the drive shaft and cam wheel operate in the same direction for outside cams which were preferred in this case. Since the relative of these two parts is the reverse of the Geneva motion, which it will now replace, the direction of the cam shaft would have to be reversed. It was found possible to add an idler gear inside the intermittent casting to accomplish this. The theory of design for the Powers cam will be explained later.

Since the television picture has 60 elementary views per second, it is evident that the shutter speed must be modified to synchronize it with the film cycle. The permitted speeds are sub-multiples of 3600 rpm.

If the shutter shaft is to remain in its present position, the advantages of larger shutter diameters are not available. Based on a given percentage of time allotted to the illumination of the film in a given shutter system, the size of the shutter opening is determined by the shutter speed. If the shutter opening is smaller than the diameter of the cone of light at the shutter plane, it becomes a limitation on the amount of light that can be passed by the optical system. Hence, it is an advantage in a disk shutter to use a single aperture and operate at 3600 rpm. In this case, it was found that for the diameter of shutter which can be accommodated, the shutter was the limiting aperture. In spite of this, calculation and subsequent experience have revealed that ample margin in illumination is available for the iconoscope.

The shutter aperture, as originally chosen, was seven per cent, hence the remainder of the time allowed for the television spot to pass through one vertical retrace operation is available to overcome any mechanical trouble due to back-lash or transients which might exist in any other part of the equipment.

The *E-7* Simplex projector is normally equipped with 1440 rpm front and rear shutters. In normal motion picture operation, this design permits greater illumination on the screen and a cooler film. The rear shutter was originally equipped with a fan. The fan was omitted in the modified design, employing 3600 rpm shutters because of the excessive power requirements. Fortunately, heating is not a problem in the projector optical system for television service.

With the new intermittent motion, space limitations would have prevented as much framing correction as permitted in the standard *E-7* Simplex projector, but the primary reason for this adjustment has largely disappeared in first-class projection rooms. Its inclusion in a standard projector is due primarily to the fact that certain



FIG. 4. Disassembled view of shutter-shaft driving system for General Electric television projector.

theaters, which may purchase new projectors, often receive film which is badly mutilated or hire operators who frequently do not attempt to maintain the careful projection practice demanded in higher grade theaters.

The use of the framing adjustment is dependent upon carelessness, either in the splicing or the inspection of the film before "running" a show or in "threading." Television, as a new industry in which each transmitter hopes to reach thousands of observers, can hardly expect to employ operators who are less careful than those of the better theaters. "Threading" mistakes would be pure carelessness with both a framing and a threading lamp especially provided to make inspection of framing a simple matter during thread-

ing. Furthermore, television should not countenance the use of film so badly mutilated that missing sprocket holes permit the picture to get out of frame after being correctly threaded; in fact, it is likely that the television studio will insist on first-run film because of the very serious loss in definition that will exist for even the smallest wear at the sprocket-holes or abrasion of the film. The former point will be more fully appreciated when it is realized that a vertical dis-

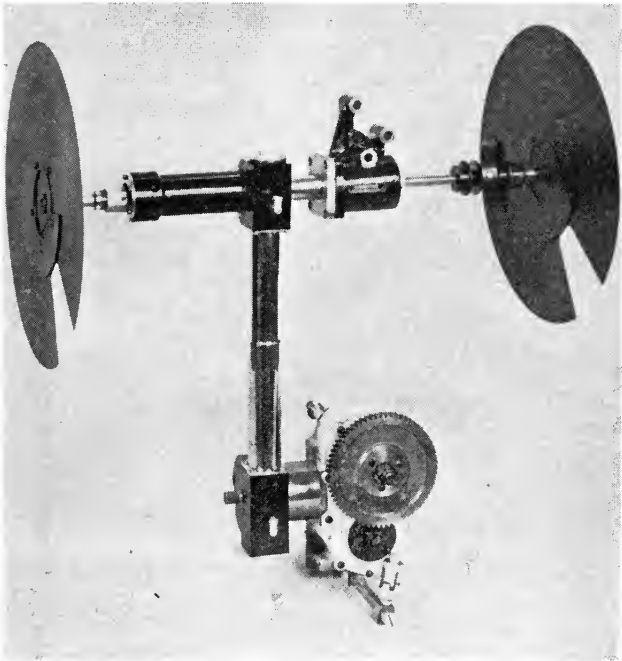


FIG. 5. Skeleton assembly view of shutter-shaft driving system for General Electric television projector.

placement of the film in the projection aperture of only 0.0014 inch from its correct position is equivalent to a shift in the television picture of one scanning line pitch. Such motion is twice the limit previously mentioned as a desirable upper limit.

A direct drive from the main drive shaft to the shutter shaft was used in order to relieve the projector gears and stud shafts of the shutter load, and to reduce the possibility of excessive speed variation in the shutter motion that would otherwise exist due to back-lash in

the gear train. These two factors were found to be of considerable importance. Since the motor operates at 1800 rpm, a two-to-one increase in speed was made necessary by the use of the 3600 rpm shutter.

Experience showed that this design, in addition to improving the safety factor on the projector gears, permitted quieter operation than would have been possible with any back-gearred arrangement on the original shutter shaft, and permitted rapid starting time. Experience has also shown that with the direct shutter drive it requires about three to four seconds to synchronize fully the motor with the line, but it is conceivable that this may vary somewhat.

In order to accomplish this, two things were necessary: (1) the original shutter-shaft drive gear on the oblique shaft in the picture head was removed and (2) a special sound head drive shaft with an extension on the coupling end was employed. The latter permitted a vertical shaft to be located just in front of the sound-head and projector casting. A special adapter was fastened to the sound-head gear box. This was designed to employ a ball bearing to support the sound-head drive shaft adjacent to the one-to-two spiral gears that were used to drive the vertical shutter shaft from the sound-head drive shaft. These gears were hardened and designed to operate in an oil bath. The component parts used to drive the shutter shaft by means of an external drive shaft are shown in Fig. 4, and a skeleton assembly of these parts is shown in Fig. 5.

A spacing bracket was fastened between the sound-head and the usual motor base bracket to accommodate the gear box for the vertical shaft. The flexible coupling originally employed between the motor and the sound-head drive shaft was used as before.

The splined gear and the spline assembly found on the original shutter shaft were removed, and an adapter was added to fit within the existing spline housing that is bolted to the main projector frame. An extended shutter bearing housing, as shown in Fig. 5, was designed to pass through the front casting of the projector head and clamp in this adapter. This established a rigid front support for the shutter shaft by the use of two sealed ball bearings at the front shutter end of this extended bearing housing and, likewise, accommodated a ball bearing for the upper end of the 3600-rpm vertical shutter drive shaft. Hardened spiral gears, operating in an oil bath, were used between the vertical drive and the shutter shafts. The ratio of speeds at this point was one-to-one. Special

attention has been given to means of preventing the rapid leakage of oil from the oil wells at each end of the vertical shaft. Oil cups were added to make daily inspection and filling of these oil wells to the proper level a simple matter.

Several additional considerations of a minor nature will be found in the problem of adapting the *E-7* Simplex projector to television service; for example, the iconoscope screen position and the tolerances in its size forced the use of a longer focal length lens than is ordinarily used. The lens chosen for this purpose was provided

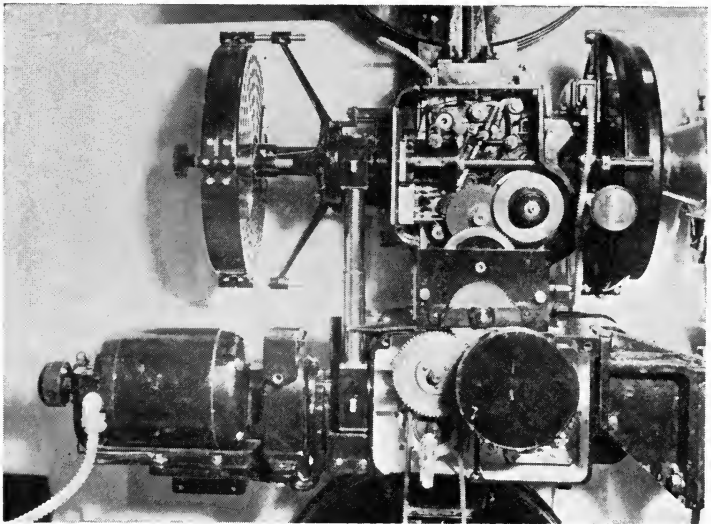


FIG. 6. Driving gear system for General Electric television projector.

with a reduced rear-barrel diameter. Therefore, a special adapter was required in the rear lens mount to clamp that portion of the projection lens which had a reduced diameter.

The projection lens should place an image of the rear shutter on the front shutter, if the latter is to cut off all of the remaining light passed by the rear shutter when both have their corresponding aperture edges on the optical axis. The preliminary design calculations indicated that an exact focus would require an impractical extension of the front end of the shutter shaft. However, since the image of the rear shutter aperture edge produced by the projection

lens was not too poor at the present front shutter position, and since some margin in closing time exists, no modification was felt desirable. Tests on the finished machine showed acceptable performance for both the opening and closing operation of these shutters as far as they were affected by focus of one upon the other.

In order to prevent accidents, the front shutter housing apertures were covered with glass. Although this is not done in professional use, it was thought desirable here in spite of the extra glass to air surfaces in the optical path. These windows also aid slightly in

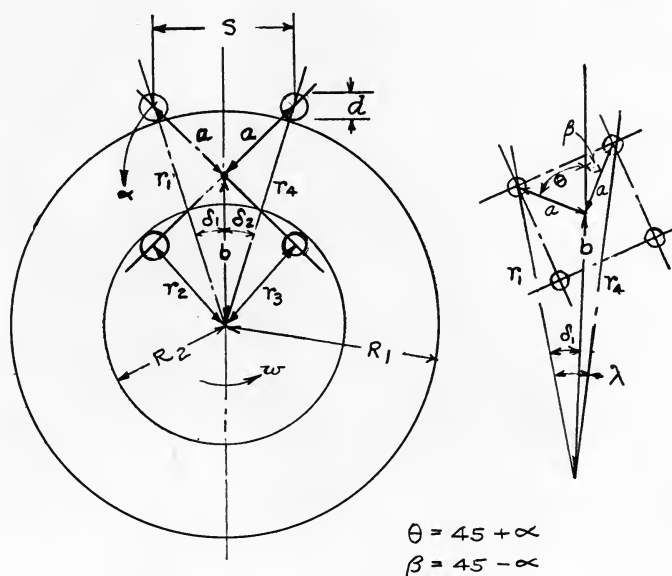


FIG. 7. Diagram showing geometry of intermittent cam system.

noise-reduction. Although the loss of light is not serious, there is a small amount of scattered light due to reflection at these surfaces. For this reason, they have been made removable.

Another optical problem was found in the attempt to focus accurately the projection lamp on the projection lens. This was due to the diameter of the lamp bulb. Since operating results have shown that a satisfactorily uniform field of illumination could be obtained at the iconoscope mosaic, no change in the standard condenser system was felt necessary.

It was said that for average lighting in normal operation at least

25 foot-candles would be required on the iconoscope mosaic, but subsequent advice from the manufacturer of the iconoscope stated that "satisfactory operation should be possible with a level of 1.5 millilumens per square centimeter for average conditions, and 3.5 millilumens per square centimeter for high light conditions." Calculations showed that the 900-watt, *T-20* projector lamp was capable of supplying this level under ordinary film conditions with at least a two-to-one safety factor. Subsequent measurements confirmed this. It was to make this possible that the 3600-rpm shutter was originally chosen. The alternative would have been an arc lamp, since incandescent sources of higher illumination were not available.

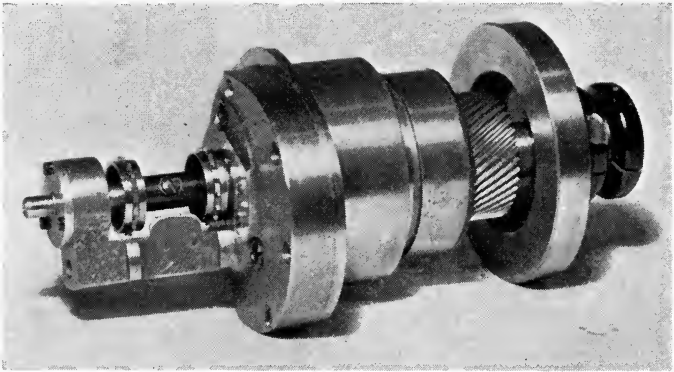


FIG. 8. Assembly view of intermittent for General Electric television projector.

Measurements of the mechanical power requirements showed that a rating of approximately $\frac{1}{3}$ hp would be required. A 3-phase, 220-volt, self-synchronous motor of this rating was used. With the larger motor, the moment of inertia of the flywheel was increased to reduce the shock due to starting acceleration, as well as any possible effects of shocks from the power system.

To further reduce the starting acceleration, adjustable 10-ohm protective resistors were used in each of the 3-phase lines. To make certain that full-line voltage would not be applied to the motor too soon, a time delay relay and contactor are used to short circuit the line resistors after the motor is synchronized with the line supply.

However, should this relay fail to short the line resistors, no loss of synchronism will result.

The synchronous motor was equipped with a d-c field winding of approximately 150 ampere turns per pole to automatically phase the projector with the electrical power system and, hence, the electrical impulses used to effect scanning.

As a final modification, means for anchoring the outer end of the stud shafts on both the main drive gear and the coupling gear, between the sound-head and the projector, has been provided. This may be seen from Fig. 6 which shows the gear train of the projector and sound-head.

Since it was found possible to use the main casting of the Geneva intermittent system in which the distance between the sprocket shaft (which was coaxial with the drive shaft) and the cam shaft was 0.7495 inch, one dimension b (Fig. 7) of the Power's intermittent

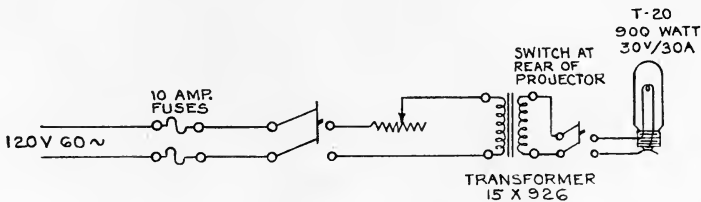


FIG. 9. Schematic connection diagram for projection lamp in General Electric television projector.

was determined. As a trial, the distance S between the centers of the locking pins was chosen as an even dimension, but was later changed to improve the design.

It was decided to employ a sine wave accelerating motion of the film, primarily because the angle of pull-down was less, in this case, than in the standard Geneva intermittent; and secondarily, to reduce any effect of film motion that might be revealed by slightly incorrect adjustments in the shutter, as well as back-lash in drive gears. Thus, the velocity of the sprocket shaft would be slow during the beginning and ending phases of this motion, but the cam would be called upon to work hardest in the middle of the moving cycle.

Design of the Intermittent Movement.—If two film frames are required for one revolution of the cam shaft then, as previously explained, only 144 degrees can be allotted to the shortest cycle, and if this frame of film is to be shown twice during this time with a maxi-

mum allowance of eight per cent for the upper limit of time of illumination, the central angle of the cam allotted to film motion can be only 66.24 degrees. Therefore, if (ω) is the displacement of the cam wheel and (α) is the angular displacement per cycle of an intermittent sprocket that accommodates four film frames per revolution, it can be seen that for sine wave film motion (see Fig. 7):

$$\alpha = 45 \left[1 - \cos \left(\frac{180}{66.24} \right) \right]$$

or

$$\alpha = 45[1 - \cos(2.7173)] \quad (1)$$

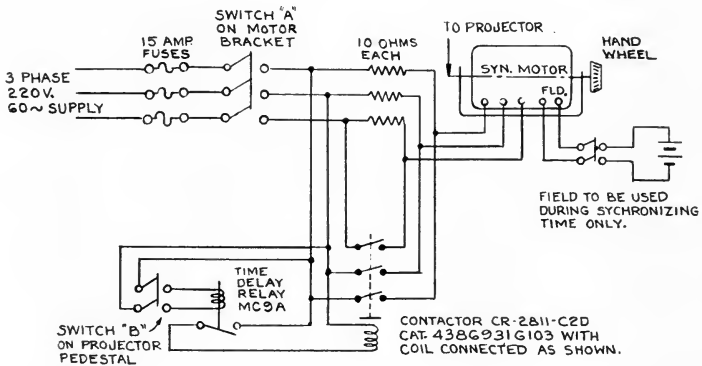


FIG. 10. Schematic connection diagram of motor starting circuit for General Electric television projector.

Hence

$$\begin{aligned} \theta &= (45 + \alpha) \\ \beta &= (45 - \alpha) \end{aligned} \quad (2)$$

Once S is chosen, it is obvious that

$$(a) = \frac{S}{2} \quad (3)$$

In the design, the diameter of the pins d was chosen as 0.1000 inch. The outer radius of the cam wheel R_1 can be determined from

$$R_1 = \left[\sqrt{\frac{S^2}{2} + b^2 + Sb} - \frac{d}{2} \right] \quad (4)$$

and the inside radius R_2 may be calculated from eq. 5

$$R_2 = \left[\sqrt{\frac{S^2}{2} + b^2 - Sb} + \frac{d}{2} \right] \quad (5)$$

The design of the actuating surfaces of the cam involves the repeated solution of eqs. 6 and 7 for small increments of displacement $\Delta\omega$, in this case 1 degree each

$$r_1 = \sqrt{\frac{S^2}{2} + b^2 + \sqrt{2}Sb \cos \theta} \quad (6)$$

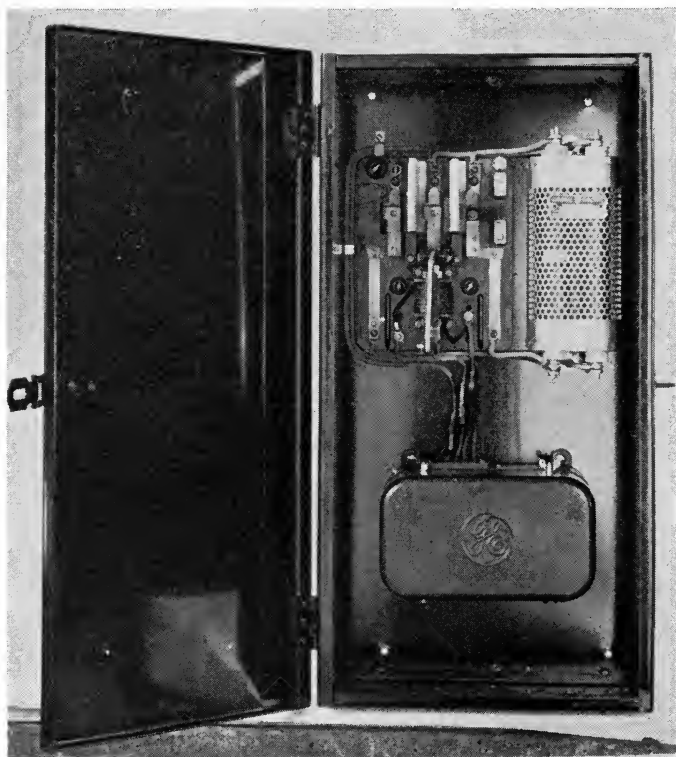


FIG. 11. Motor starting equipment for General Electric television projector.

$$r_4 = \sqrt{\frac{S^2}{2} + b^2 + \sqrt{2}Sb \cos \beta} \quad (7)$$

To complete the design of the cam wheel the other coordinates for both r_1 and r_4 must be calculated. This may be accomplished by determining the included angle λ between these two vectors, then the angle between either and the central vector b , for example, δ .

Thus

$$\lambda = \arccos \left(\frac{r_1^2 + r_4^2 - S^2}{2r_1r_4} \right) \quad (8)$$

$$\delta_1 = \arccos \left(\frac{r_1^2 + (b^2 - a^2)}{2r_1b} \right) \quad (9)$$

From these equations all of the necessary details for the construction of the cam wheel and pin wheel can be obtained.

The completed cams worked very well requiring no more power

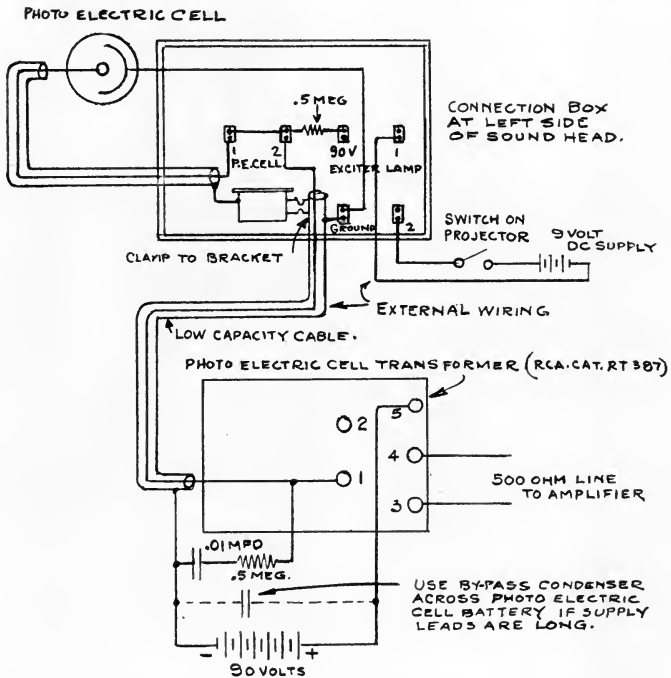


FIG. 12. Schematic connection diagram for sound system in General Electric television projector.

than the intermittent system they replaced, and producing a screen picture of exceptional steadiness. An assembled view of the intermittent movement may be seen in Fig. 8.

The Sound Head.—The sound-head used was the Simplex design employing the RCA Rotary Stabilizer. It utilizes a single stage of mechanical filtering to reduce the variations in film velocity, at the sound scanning point, to an acceptable amount. Since this device has been previously described before the Society, no further

description will be given here. For the mathematical theory the reader may refer to a previous article by the author, "The Technical Aspects of the High-Fidelity Reproducer" (*J. Soc. Mot. Pic. Eng.*, XXV (Oct., 1935), p. 289).

The operation of this form of sound-head has been very satis-

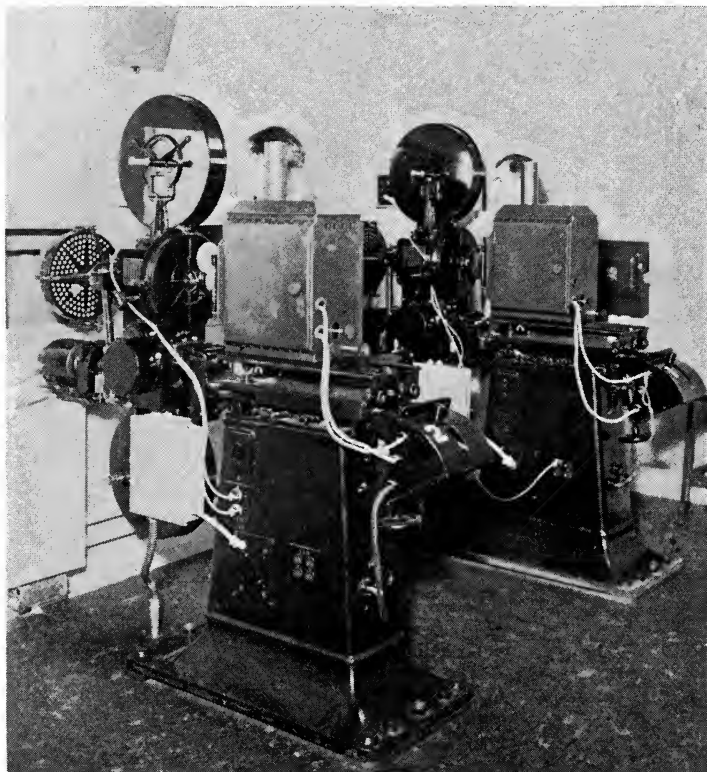


FIG. 13. Film projection room in General Electric television Studio *WRGB*.

factory. Although better designs are possible, it was felt that the economy of commercially available devices more than offsets the difference in performance.

The only modification necessary was to have the sound-head supplied with the special shaft previously mentioned having, in addition, the proper gear reduction for an 1800-rpm or synchronous

motor rather than for the 1750-rpm induction motor generally supplied. The adapter, *etc.*, necessary to drive the vertical shaft geared to the shutter shaft has been previously described.

Electrical Features.—The filament of the projection lamp is supplied from a step-down transformer and preferably should be

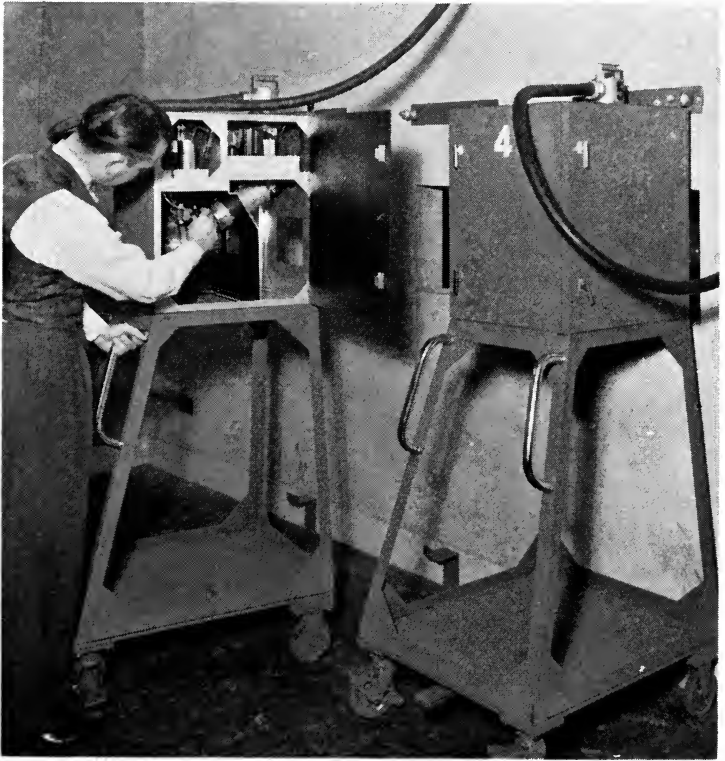


FIG. 14. Television film camera room in General Electric television Studio WRGB.

brought to normal voltage (30 volts) slowly. There are several methods by which this may be accomplished, but a simple variable series resistance of approximately 15 ohms, 10-ampere rating, in the primary circuit of the transformer, seems as economical and satisfactory as any. The wiring diagram, which may conveniently include the switch at the rear of the projector pedestal, is shown in

Fig. 9. If desired, the filament transformer may be mounted within the pedestal.

Adjustable protective resistors have been specified in the 220-volt supply lines for the 3-phase synchronous motor. These resistors limit the initial starting voltage to that just capable of starting the motor. As previously mentioned, a time delay relay and contactor have been provided to automatically short circuit these resistors. The connection diagram is shown in Fig. 10. A photograph of the starting box, including the three protective resistors, the time delay relay, and the contactor, is shown in Fig. 11.

A framing light, which is used to determine whether or not the film is properly framed in the film gate, is located in the demountable light shield that has been placed between the rear shutter housing and the film gate. A step-down transformer, 120 to 6 volts, is used to operate this lamp from any 120-volt, 60-cycle source. The framing lamp is controlled by a nickel-plated rod found just above the light shield.

The framing lamp is normally raised above the projection light beam during normal operation, but upon moving the fire shutter lift lever forward, the fire shutter is raised and the framing lamp is automatically switched on and swung down to the optical axis. Thus, the film frame in the gate will be illuminated with sufficient intensity for framing inspection purposes.

Since the photoelectric cell is to be transformer coupled to the amplifier, care should be exercised to keep the electrostatic capacity of the cable between the photoelectric cell and the primary of the coupling transformer below 50 mmfds. The photoelectric cell transformer should therefore be relatively close to the projector. Due to its well balanced design and partially shielded location little, if any, stray field "pick-up" will be experienced. Because of the relatively high overall gain, the photocell transformer should be mounted to prevent microphonic excitation due to mechanical vibration. The diagram of connection is shown in Fig. 12.

The motion picture projection room of the General Electric Company's television studio, Station *WRGB*, in Schenectady is shown in Fig. 13, the associated camera room, in Fig. 14.

REPORT OF THE COMMITTEE ON SOUND*

Hollywood sound engineers are currently devoting the major part of their attention toward maintaining the present quality of sound. Research and development of new equipment and methods have been sharply curtailed in some studios and stopped in others for the duration. However, certain improvement programs are being carried forward where equipment had been ordered before the war, and where delivery has been completed.

A number of major sound development projects, which had been started before the war, have been set aside for the duration. These projects include further work on stereophonic sound, control track recording, multiple horn systems, *etc.*

Economies.—Considerable attention has been given to further economies in operating techniques and toward the conservation of strategic materials. The preselection of both picture and sound takes is being widely employed. By this preselection operation only the takes which are to be printed are sent to the laboratory for development, thereby saving considerable quantities of chemicals in the developing solutions. Since only one side of the sound negative stock has been exposed the non-print out-takes are reassembled into 1000-ft rolls, reversed, and the unexposed edge of this film used for daily sound prints, leader stock, and other uses. Split film is another method used for the conservation of film.

The use of dry batteries has been markedly reduced by the conversion of plant equipments to a-c operation.

Vacuum tube types have also been standardized in many equipments.

The following paragraphs outline a number of the features of a typical Hollywood sound-recording channel as used today:

Microphone.—Directional type microphones are being more widely used to reduce pick-up from extraneous noise sources and to reduce acoustic pick-up difficulties inherent in wartime set construction.

Microphone Booms and Poles.—The present trend is to use lighter weight and more portable booms. The gunning devices have been

* Presented at the 1943 Spring Meeting at New York.

improved and have made easier the operation of placing the directional microphone. The use of the "fish-pole" type of mike boom has increased in recent years. This type of microphone pole consists of a telescoping "Dural" tube fitted with a standard microphone hanger. When used on the floor it is either held in the hand of a boom man or supported by an auxiliary stand similar to a portable lamp stand which has been fitted with a quiet roller to assist the operator in supporting the boom and in properly directing the microphone. For high use the pole is equipped with a ring placed near its balance point by which it may be suspended by a rope from a point directly over the set. By this means the microphone may be "flown" into operating positions that would be difficult to reach in any other manner. The use of the fish-pole type of mike boom has proved most expedient for use on Army location pictures.

Microphone Preamplifiers.—Feedback preamplifiers are replacing earlier types to reduce noise and to provide better quality. The wide use of low impedance microphones allows the preamplifier to be placed at almost any convenient location on the set.

Mixer Control Panels.—The mixer control panel now in general use is mounted in a portable case along with associate equipment, such as volume indicator, signal lights, telephone subset, and dialog equalizers. This case is usually mounted on a portable wheeled table so that the operating position may be close to the action to be recorded. Lighter and smaller equipment components are needed for these mixer panels to increase further their ease of handling on recording sets.

Booster Amplifiers.—Booster amplifiers are usually mounted in the mixer case and are used when it is necessary to send the sound currents some distance to the main amplifier.

Main Amplifiers.—Probably the greatest change in amplifiers in the past several years has been the advent and adoption of the compressor type or limiting type of main amplifier. By the use of this amplifier, modulator overshooting, with its inherent distortion, has been eliminated. Dialog and sound effects of excessive loudness are now electronically compressed to levels within recording limits.

As in the case of preamplifiers and booster amplifiers, feedback is being more widely used to increase the signal-to-noise ratio in the recording circuits and to reduce all forms of distortion.

Monitoring Facilities.—The dynamic headset has largely replaced the monitor booths formerly employed on production stages. The small plastic molded ear-piece types of headsets are also being exten-

sively used because of the improved coupling to the ear. Monitor rooms are used for dubbing and scoring work because of the fixed nature of these facilities and the need for reverberation characteristics simulating those of a theater auditorium.

Preëqualized Recording of Speech and Music.—Preëqualization for original recordings, both speech and music, is being used by some sound departments, and a standard preëqualization characteristic is under consideration. No preëqualization of the release product is being considered for the duration.

Recording Machines.—Sound-recording machines have been materially improved during the past few years. Various types of sprocketless recording drums of both magnetic and oil-damped types are being employed to reduce flutter, resulting in a definite improvement in sound quality. Improved fidelity of variable-density recorders has also been attained by the use of auxiliary cylindrical lenses to reduce the effective valve-image height on the film. This improvement effectively eliminates high-frequency intermodulation effects and increases the signal-to-noise range, since greater valve amplitudes may be used.

The optical efficiency of recording machines has been improved by the use of coated lenses. This has been one of the important factors in promoting the increased use of fine-grain films that require higher light intensities. Recorders are also being equipped with photographic slating devices that photograph pertinent information for each take in the sound-track area. Solenoid operated punches are also being used for marking the film for preselection purposes.

Automatic starting and stopping circuits are being used by some studios to start, stop, and synchronize cameras and recorders from a remote position.

Films for Recording.—The use of fine-grain films for both sound negative and prints and release positive is now almost universal. The reduction in film-surface noise has permitted a much higher quality of reproduction, particularly for critical dialog and musical sequences.

Modulators.—There is an increasing tendency, for original variable-density recording, toward the use of 200-mil push-pull recording. It is to be expected that the use of push-pull recording for all original work will increase in the future. The use of Class *B* and Class *A-B* variable-area track is also finding favor in some of the studios, these tracks being particularly desirable for super-portable types of record-

ing channels where the elimination of the weight of the noise-reduction unit is desirable.

The use of the super-portable type recording channels has proved advantageous in the recording of Army training films on location.

The resonant rise and high-frequency transients of light-valves are now being eliminated by the use of electrical feed-back networks that also provide additional damping for the valve, thereby reducing transient response. The damping of galvanometers for variable-area recording by the use of tungsten-loaded rubber has also proved highly effective.

Re-Recording.—Because original sound-tracks are much improved by devices such as push-pull track, preëqualization, 200-mil tracks and Class *A-B* and *B* tracks, it has become necessary to re-record the entire sound-track for release purposes. Many unique equalizers, both automatic and manual in operation, are used throughout to maintain a standard fidelity.

Film Development Control.—The intermodulation meter for variable-density track and the cross-modulation test for variable-area track are now being employed universally to establish correct sound-film development parameters.

Sensitometric control has been standardized throughout the industry by the use of a new electronic densitometer of the intergrating-sphere type.

Automatic developer replenishment methods are finding wider use in the laboratories because of the increased uniformity in results that can be attained.

Recording Stages.—Numerous improvements have been made in the design of scoring stages for more effective recording of music. Various types of orchestra shells have been put into service with a definite improvement in sound quality.

Motor Systems.—Improved test equipment has been designed for the rapid location of troubles in stage motor systems, particularly when connected to camera, playback, and transparency equipment. The slip-clutch type of synchronous distributor is also finding increased use. There is a trend toward the standardization of 1440-rpm stage drive motors for camera, playback, transparency, and projector equipment. The handling of transparency projectors is being expedited by the use of reversible motors so that all picture films may be rewound to any required sync mark in a minimum of time without rethreading.

REPORT OF SOUND COMMITTEE

COMMITTEE ON SOUND

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A NOTE ON THE PROJECTION LIFE OF FILM*

D. R. WHITE and C. DEMOOS**

Summary.—Tests with intermittent sprockets of different diameters have shown that the maximum projections which can be attained depends greatly on a diameter within the range of 0.943 inch to 0.965 inch diameters, about a $2\frac{1}{2}$ per cent range. The sprocket pitch for best wear is greater than the apparent match between static perforation measurements and sprocket dimensions. This is in accord with the view that the elastic characteristics of the base are important at this point in the projection cycle. Tests with different pressures on the film gate show that this setting is an important factor affecting wear at the intermittent sprocket. The way by which perforations tear is different under the following two conditions: (a) film pitch less than best match for sprocket pitch, and (b) film pitch greater than best match for sprocket pitch.

The conditions that are required to attain a maximum film life during projection long have been of interest in the motion picture industry, but the subject has rarely been of as great importance as it is today. War conditions have emphasized the importance of all steps leading to conservation of materials.

Under the most favorable conditions set up in the tests, an average projection life of 2400 projections was reached. Such a large number of projections is not commonly attained under commercial conditions. There are many reasons for this: in the first place, many pictures do not require such a large number of projections from individual prints. Such a life would account for nearly two years of continuous use, if projected three times per day. It is desirable to cover the theaters with a greater number of prints effecting shorter periods from first to last showing than would be achieved if schedules were worked out on the basis of long, individual print life. In the second place, accidents in handling in projection and rewind rooms tend to produce scratches and breaks which mar the film long before it would deteriorate under laboratory conditions.

The relationship between intermittent sprocket diameter, film pitch and resultant wear was studied. For the purposes of this test, the unwind and rewind magazines were removed from a pro-

* Presented at the 1943 Spring Meeting at New York.

** E. I. Du Pont de Nemours & Co., Photo Products Department, Parlin, N. J.

jector and auxiliary idler rolls introduced to permit the continuous projection of a short loop of film. This arrangement removed all tension from the pull-down sprocket and, of course, changed conditions at the hold-back sprocket since there was now no tension corresponding to the normal pull from the wind-up. The relief of tensions at these points reduced the system to one in which the chief sprocket-hole wear was clearly traceable to the intermittent sprocket.

It was not possible to duplicate completely all the various temperature and humidity conditions which might be encountered in trade practice, but throughout these tests the arc was used with sufficient warm-up time to keep the gate and the machine at a normal operating temperature. The machine was in an air-conditioned room, and thus the entire system was reasonably reproducible.

Previous experience had shown that only a small departure from current commercial standards would be required to produce marked effects on film wear. Accordingly, four sprockets were made:

Sprocket	Root Dia.	Pitch at Median Line of Film
No. 1	0.943	0.1863
No. 2	0.948	0.1873
No. 3	0.956	0.1889
No. 4	0.965	0.1907

With this series of sprockets it was possible to show the effect of relative change in film and sprocket pitch. Results of the first series of tests are shown in Table I.

TABLE I

Film Base	Film Pitch	Projections with Sprocket			
		No. 1	No. 2	No. 3	No. 4
Nitrate—Sample 1	0.1864	360	<i>1251</i>	1070	774
Nitrate—Sample 2	0.1868	365	585	<i>1123</i>	468
Safety—Sample 1	0.1865	90	190	<i>250</i>	162
Safety—Sample 2	0.1863	144	232	<i>380</i>	374

The greatest number of projections attained, as shown in italics in Table I, shows strikingly that the longest life occurred where sprocket diameters were larger than calculated for a perfect fit, as judged from static measurements of film and sprocket dimensions. It was decided to investigate this observation further. The projector with which the work was done had been in use for some time in wear studies and conditions of use had been chosen to tear the film to pieces rapidly. No changes were introduced when the test

was started, but a recheck showed that the gate tension was heavier than normal and might have caused too great a pull and elongation of the film. Therefore, a second series was run after the gate tension was reduced, with the results shown in Table II.

TABLE II
"Normal" Gate Tension

Film Base	Film Pitch	Projections with Sprocket			
		No. 1	No. 2	No. 3	No. 4
Nitrate—Sample 1	0.1869	1215	1250	2350	1935
Nitrate—Sample 2	0.1867	810	1575	2439	2340
Safety—Sample 1	0.1869	205	545	450	445
Safety—Sample 2	0.1866	679	1263	1386	1390

This table shows a considerable increase in projection life over the previous conditions, but, surprisingly, it shows no reduction on the average in sprocket diameter for maximum projections.

Such effects are difficult to explain. In the first series the indication of a maximum is so definite, at a sprocket pitch greater than that of the static film dimensions, that a general drop in the sprocket pitch for maximum life was anticipated with a reduced gate tension. Table II does not show any such drop.

However, the favorable showing on projection life is seen to be definite regardless of an explanation of these details of the data.

A study of the worn perforations of the film showed different, typical tears, depending on the relative pitch of film and sprocket during the test. When the sprocket is small in comparison with the film pitch, the entering tooth rubs the sprocket-hole, tending to break or tear it with a push toward the surface of the film and away from the sprocket itself. Conversely, when the sprocket is large in comparison with the film, the film drags on the tooth as it withdraws from the film tending to break or tear it by a pull toward the film surface next to the sprocket. In the case of the best fit no predominant tear could be found; in fact, many perforations had a notch worn in them the width of a sprocket tooth and a few thousandths of an inch deep.

The results of the tests emphasize the fact that small differences of pitch can be important in determining limits of projection life, and they suggest that much greater projection life is possible than is usually achieved under theater and exchange conditions.

SOME CHARACTERISTICS OF AMMONIUM THIOSULFATE FIXING BATHS*

DONALD B. ALNUTT**

Summary.—A brief description of the history and nature of ammonium thiosulfate is given. Several practical formulas employing this agent are presented and their advantages discussed. Some of the differences in characteristics between the ammonium thiosulfate and sodium thiosulfate fixing baths are pointed out.

An explanation is offered to account for the apparent discrepancies in the effects of concentration on clearing time reported by previous investigators. The speed of fixation of ammonium thiosulfate is shown to be greater than sodium or lithium thiosulfates and greater than mixtures of ammonium chloride and sodium thiosulfate.

HISTORICAL

The author is indebted to J. S. Mertle,¹ Technical Director, International Photo-Engravers Union, for the following brief account of the discovery and early application of ammonium thiosulfate to the photographic process.

The fact that ammonium thiosulfate will dissolve silver halides was established long before the development of the photographic process as it is known today. Sir John F. W. Herschel is credited with the discovery of the solvent action of the thiosulfates on silver chloride. His paper,² published in 1819, mentioned ammonium thiosulfate as one of the thiosulfates which exerts solvent action on silver chloride. This is probably the earliest mention of the use of ammonium thiosulfate for this purpose. The first specific mention of the increased rate of fixing of sodium thiosulfate in the presence of ammonia or ammonium carbonate was made in 1866 by John Spiller,³ who, two years later,⁴ recommended it as a fixing agent because its greater solubility in water induced its quicker elimination from plates and papers during washing after fixation. Practically the same idea was voiced in 1892 by Labarre⁵ who pointed out the easy solubility of ammonium thiosulfate and its more rapid action as compared to an equally concentrated solution of the sodium derivative.

* Presented at the 1942 Fall Meeting at New York.

** Research Laboratories, Mallinckrodt Chemical Works, St. Louis, Mo.

Eduard Valenta⁶ in 1895 investigated the fixing action of ammonium thiosulfate. He could see no advantage in its use, but qualified his opinion with the statement that commercial samples of the salt, at that time, seldom were free from contamination. In spite of Valenta's verdict, Eduard Liesegang⁷ maintained his own faith in the superiority of the ammonium compound. His method of preparing the salt involved the reaction of sodium thiosulfate solution with barium chloride, followed by treatment of the precipitate with ammonium carbonate.

In 1906, the Viennese, Karl Seib, introduced a commercial preparation, "Rapid-Fixage," which was not a true ammonium thiosulfate, but was converted to this state by admixture in water with ammonium carbonate. The same year the German trust, Agfa,⁸ introduced a commercial fixing salt of ammonium thiosulfate constituency under the name "Agfa-Rapid Fixing Salt" (Agfa-Schnellfixiersalz); it was patented in Britain (No. 25,869) in 1906.

Apparently ammonium thiosulfate has not heretofore been available in this country on a commercial scale in the purity required for photographic use. It is now being offered as a stable 60 per cent solution and as a stable anhydrous crystalline solid.

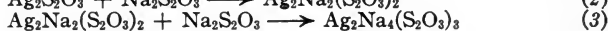
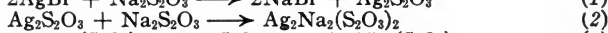
CHEMICAL NATURE

Chemically, ammonium thiosulfate is similar to sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$, except that the sodium is replaced by the ammonium radical to give the molecular formula $(\text{NH}_4)_2\text{S}_2\text{O}_3$. Ammonium thiosulfate crystallizes without water of crystallization in colorless, glistening plates or sword-shaped monoclinic crystals. Its molecular weight is 148 compared with 248 for sodium thiosulfate crystals. Thus six parts of anhydrous ammonium thiosulfate will take the place of ten parts of sodium thiosulfate crystals in any given chemical reaction.

Ammonium thiosulfate reacts chemically in much the same way as the other soluble thiosulfates. It is readily decomposed by heating, and its solutions sulfurize readily when acidified in the absence of sulfite. It has a strong solvent action for silver, mercurous and thallos chlorides, bromides, and iodides.

All of the soluble thiosulfates appear to have varying degrees of solvent action on silver salts. Although the precise chemical reactions involved in the formation of soluble silver compounds from

insoluble silver halides are still obscure,^{9, 10} the reactions are generally indicated^{10, 11} as occurring in several steps as follows:



As can be seen, each succeeding complex formed contains a higher ratio of sodium to silver so that the complex formed in eq. 3 is the highly soluble disodium-silver thiosulfate. The solubilities of these complexes vary in inverse ratio to their silver content.

According to Klempt, Brodkorb, and Erlbach,¹² the concentration and density of saturated solutions of $(\text{NH}_4)_2\text{S}_2\text{O}_3$ at various temperatures are as follows:

TABLE I

Per Cent by Weight and Density of Saturated Solutions of $(\text{NH}_4)_2\text{S}_2\text{O}_3$ at Various Temperatures

Temperature, °C	Per Cent	Density
-10 (14°F)	60.3	1.322
0 (32°F)	61.6	1.332
20 (68°F)	64.5	1.342
40 (104°F)	67.2	1.347
60 (140°F)	69.4	1.351

A 60 per cent solution of ammonium thiosulfate is near the saturation point and may deposit crystals in extremely cold weather. For this reason, it is impractical to handle solutions of greater strength.

The relation between the concentration and specific gravity of aqueous solutions of ammonium thiosulfate at 25°C (77°F) is shown in Fig. 1.

The following table gives the data on which the curve in Fig. 1 is based:

TABLE II

Concentration and Specific Gravity of Ammonium Thiosulfate Solutions at 25°C (77°F)

Concentration in Per Cent by Weight	Specific Gravity at 25°C
4.35	1.0200
9.23	1.0454
14.58	1.0743
19.32	1.1000
29.07	1.1598
38.84	1.2076
53.39	1.2641

CHARACTERISTICS

The time of clearing, and consequently the time of fixation of an ammonium thiosulfate fixing bath, is approximately one-fourth that of the common sodium thiosulfate fixing baths.

Fixing baths made with ammonium thiosulfate appear to retain their hardening action over a wider range of pH than the sodium thiosulfate baths. The commonly used hypo-fixing baths appear to lose their hardening action when the pH has been raised to between 5.5 and 5.8, although their fixing power still may be good; but, an ammonium thiosulfate aluminum salt bath will retain satisfactory hardening action up to a pH of 6.5 to 7. This characteristic

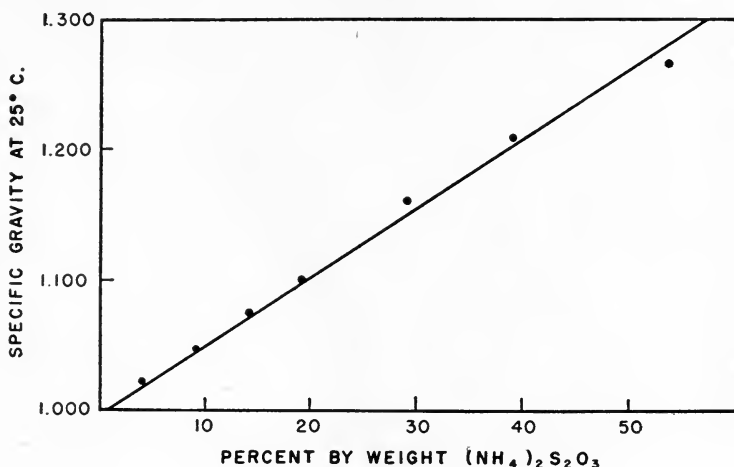


FIG. 1.

is a definite advantage, since it means that an ammonium thiosulfate fixing bath will harden satisfactorily more film than will a similar sodium thiosulfate bath.

Concentrated fixing baths requiring only dilution for use can be readily prepared with ammonium thiosulfate. This is due not only to the slightly greater solubility of ammonium thiosulfate, but to the fact that equal or greater efficiency can be obtained from the lower concentration of ammonium thiosulfate. Thus, formula *ATF-1*, which follows, can be prepared as a concentrated solution in only 25 per cent of its final volume, whereas a comparable hypo bath would require 40 per cent of its final volume for a concentrated

solution in which all the ingredients would be maintained in complete solution.

Little difference is observed in the clarity of films just after fixation in either ammonium or sodium thiosulfate fixing baths. However, films fixed in ammonium thiosulfate solutions of greater than normal concentration were clearer just after fixation than those fixed in similar concentrations of sodium thiosulfate. This is especially true of *x*-ray films.

It is generally known that prolonged treatment of a photographic image in an acid-hardening fixing bath will reduce the density of the silver deposit. Experiments designed to compare the reducing action of ammonium thiosulfate and sodium thiosulfate fixing baths, both fresh and used, indicate that the reducing action of ammonium thiosulfate is no greater than that of sodium thiosulfate, except for papers and process film.

The recently published *F-7* formula of Crabtree *et al.*,¹³ using ammonium chloride to give greater fixing speed, was compared with ammonium thiosulfate fixing baths, both as to speed and hardening properties. It was found that ammonium chloride additions to regular sodium thiosulfate fixing baths increased their speed considerably, but that these baths were still slower in their fixing action than straight ammonium thiosulfate baths. Furthermore, ammonium chloride seems to decrease the hardening action of such baths.

It was thought that the greater solubility of ammonium thiosulfate might increase the ease of washing it out of emulsions. However, washing experiments indicate that this agent is eliminated at about the same rate as sodium thiosulfate.

FORMULATION

The modern acid-hardening fixing bath is expected to perform other functions besides transforming silver halides into soluble salts. Some of these other functions are: hardening the emulsion, stopping development, and preventing stains. In order to accomplish these results satisfactorily, an acid-hardening fixing bath should have certain qualities. Crabtree and Hartt¹⁴ enumerate six important requirements for a satisfactory acid-hardening fixing bath which, briefly summarized, are as follows:

- (1) It should fix with sufficient rapidity.
- (2) It should not sulfurize.

- (3) It should not form a sludge.
- (4) It should not cause blisters on film.
- (5) It should produce sufficient hardening.
- (6) It should have a satisfactory service life.

In devising formulas using ammonium thiosulfate, our aim was to produce fixing baths which would retain all of the speed of fixing possessed by simple solutions of the agent; which would have no deleterious effect on the photographic emulsion; and also would have sufficient hardening action. Other requirements, such as stability of the solutions, service life of the bath, *etc.*, were considered of secondary importance.

Baths were first formulated using ammonium compounds throughout; that is, ammonium thiosulfate, ammonium sulfite, and ammonium alum. Such baths were found to have no advantages over baths made with ammonium thiosulfate, sodium sulfite, and potassium alum. In fact, the speed of fixation was found to be influenced almost entirely by the concentration of the ammonium thiosulfate used in the formulation of the bath. For this reason the formulas devised and tested were based largely on known satisfactory formulas by substituting ammonium thiosulfate for sodium thiosulfate in varying proportions.

Ammonium Thiosulfate General Purpose Acid-Hardening Fixing Bath.—This bath contains approximately 150 grams of anhydrous ammonium thiosulfate per liter. At the time this concentration was chosen, it was believed that this strength produced the most rapid fixing action, although later it was learned that the speed of fixation increased as the concentration was increased up to a saturated solution. The amount of sodium sulfite was chosen to conform, in general, to concentrations used in known satisfactory fixing baths. The amount of boric acid was chosen for the same reason, since baths using this concentration are known to inhibit satisfactorily the precipitation of an aluminum sulfite sludge.

In sodium thiosulfate baths, aluminum chloride is said to have several advantages over alum,¹⁵ the most important of which is its increase in the sludging and sulfurization life of the bath. It was found experimentally that aluminum chloride was a satisfactory hardening agent in ammonium thiosulfate baths. The amount of acetic acid was determined by empirical methods so that the pH produced was in the known critical range for the proper functioning of the aluminum as the hardening agent. The selection of aluminum

chloride as the hardening agent made it possible to use this formula as a concentrated ready-to-use, two-solution fixing bath. The *ATF-1* formula is given both in the ready-to-use form and in a concentrated solution form suitable for liquid packaging.

ATF-1

Ammonium Thiosulfate General Purpose Acid-Hardening Fixing Bath

Ingredients	One Liter	
	Ready-to-Use	Concentrated
Water	700 cc	
Ammonium thiosulfate, 60 per cent solution	185 cc	185 cc
Sodium sulfite, anhydrous	12 gm	12 gm
Acetic acid, glacial	9 cc	9 cc
Boric acid	7.5 gm	7.5 gm
Water, enough to make		250 cc
Aluminum chloride hexahydrate	12.5 gm	12.5 gm
Water, enough to make	1000 cc	25 cc

Dissolve the chemicals in the order given. Add the acetic acid slowly while stirring. Dissolve the boric acid in a small amount of hot water before adding it. When making the concentrated formula, keep the aluminum chloride solution separate until ready to make up the bath. To prepare a ready-to-use fixing bath, the concentrated solution should be diluted with 750 cc of water and the aluminum chloride solution added slowly while stirring.

The *ATF-1* formula has been found to have good service life, excellent hardening action, and rapid clearing action. When made up in concentrated form, the solutions are remarkably stable. Because of this latter property, this bath is well suited for *x-ray* work.

Ammonium Thiosulfate-Chrome Alum Acid-Hardening Fixing Bath.—Formula *ATF-2* was developed to produce a fixing bath whose hardening action could keep pace with its fixing action. It is well

ATF-2

Ammonium Thiosulfate-Chrome Alum Acid-Hardening Fixing Bath

Ingredients	One Liter
Water	700 cc
Ammonium thiosulfate, 60 per cent solution	185 cc
Sodium sulfite, anhydrous	15 gm
Sulfuric acid, 5 per cent	80 cc
Potassium chrome alum	15 gm
Water, enough to make	1000 cc

Dissolve the chemicals in the order given. To make sulfuric acid 5 per cent, add 5 cc of C. P. acid to 95 cc of cold water slowly with rapid agitation.

known that chrome alum gives not only extreme hardening of gelatin emulsions, but that this action is relatively rapid when it is used in a bath whose acidity is properly adjusted.

This bath produced satisfactory hardening within the time necessary for it to clear most types of emulsions. In common with most chrome alum acid-hardening fixing baths, the service life of this bath is short and it has poor keeping qualities.

Ammonium Thiosulfate-Chrome Alum Acid-Hardening Fixing Bath (Suitable for Dry Packaging).—Since the rapid hardening, rapid clearing type of fixing bath would be useful largely in military operations, race tracks, news work, *etc.*, it was considered desirable to create a formula of this type that could be packaged as dry chemicals to facilitate the distribution of such a fixing bath. Formula *ATF-3*, which follows, takes advantage of the strong acidic properties of the stable, solid sulfamic acid^{16,17} to produce a fixing bath having essentially the same properties as *ATF-2*. It was also found necessary to use a slightly dehydrated form of potassium chrome alum, dried to about 85 per cent of its original weight, to give a mixture of acidic ingredients that would not cake in the package. The amount of ammonium thiosulfate was also increased in this bath to take advantage of the slight but important decrease in clearing time which this concentration would produce.

ATF-3

Ammonium Thiosulfate-Chrome Alum Acid-Hardening Fixing Bath (Suitable for Dry Packaging)

Ingredients	One Liter
Ammonium thiosulfate, anhydrous	200 gm
Sodium sulfite, anhydrous	15 gm
Potassium chrome alum (dried)	13 gm
Sulfamic acid	9 gm

(To make potassium chrome alum (dried), dry the regular chrome alum slowly to drive off about 15 per cent of its original weight.)

Mix the ammonium thiosulfate and the sodium sulfite and package in a large container. Mix the alum and the acid and package in a small separate container. For use, dissolve the ingredients of the large container in approximately 700 cc of water. Dissolve the acidic ingredients from the smaller container in about 100 cc of water and add this solution to the former slowly while stirring. Make up the final volume to 1000 cc.

Fixing baths made from powders compounded according to the *ATF-3* formula behave very similarly to the *ATF-2* fixing bath. The powders themselves have proved to be reasonably stable over a storage period of four months except that the solid ammonium thiosulfate has a tendency to cake slightly. This tendency has not been found to be detrimental to the use of this type of package.

Ammonium Thiosulfate General Purpose Acid-Hardening Fixing Bath (Suitable for Dry Packaging).—A formula consisting entirely of solid ingredients that would give a bath similar in properties to the *ATF-1* fixing bath was also developed. In this project, we were guided by the recent work of Woosley and Pankhurst¹⁸ who made use of the combination of sodium acetate and sodium bisulfate to produce the necessary acidity in their fixing baths. These authors used equal weights of acetate and bisulfate. We found that a ratio of bisulfate to anhydrous acetate of three to two gave a bath of proper pH for satisfactory functioning of the hardening agent.

ATF-4

Ammonium Thiosulfate General Purpose Acid-Hardening Fixing Bath (Suitable for Dry Packaging)

Ingredients	One Liter
Ammonium thiosulfate, anhydrous	150 gm
Sodium sulfite, anhydrous	15 gm
Sodium acetate, anhydrous	21 gm
Boric acid	10 gm
Sodium bisulfate	31 gm
Potassium alum	15 gm

Package the ammonium thiosulfate and sodium sulfite in a large container. Make a separate moisture-proof packet of the sodium acetate and place it in the large package. Mix the boric acid, sodium bisulfate, and potassium alum and package in a small container. To make up the solution, dissolve the contents of the large package in about 700 cc of water and add the sodium acetate from the small packet. Dissolve the contents of the smaller package in about 200 cc of warm water. Add the second solution to the first slowly while stirring.

Exhaustion tests on this bath indicate that it has good service life, produces satisfactory hardening, and has satisfactory capacity for carried-over developer. Keeping tests have not been completed on the dry packaged chemicals, but after two months they appear to be stable.

Ammonium Thiosulfate General Purpose Acid-Hardening Fixing Bath.—Since aluminum chloride hexahydrate is not a common photographic chemical, a fixing bath having characteristics similar to the *ATF-1* was developed, using the regular photo grade of potassium alum. It was also found that by increasing the amount of the ammonium thiosulfate to 200 grams per liter a considerable extension of the service life of the bath could be obtained. Furthermore, the solid ammonium thiosulfate was designated in this formula, since this type of material is more adaptable to commercial handling. The *ATF-5* formula, which follows, incorporates these modifications.

ATF-5

Ammonium Thiosulfate General Purpose Acid-Hardening Fixing Bath

Ingredients	One Liter
Water	700 cc
Ammonium thiosulfate, anhydrous	200 gm
Sodium sulfite	15 gm
Acetic acid, 28 per cent	55 cc
Boric acid	7.5 gm
Potassium alum	15 gm
Water, enough to make	1000 cc

Dissolve the chemicals in the order given. Dissolve the boric acid in a small amount of hot water and add it to the bulk of the solution.

This bath was found to have an exceptionally long service life, and it produced satisfactory hardening over a long period of time. All of its ingredients, except the ammonium thiosulfate, are regularly available in any photographic laboratory.

A more complete description of the properties of these formulas will be given in the experimental section that follows. It is believed that ammonium thiosulfate can be used to advantage not only in the general type of fixing bath, but also in formulas designed for special types of work, such as non-hardening fixing baths and replenishers for acid-hardening baths.

EXPERIMENTAL

Rate of Fixing.—The chief advantage of the ammonium thiosulfate fixing bath is the rapidity with which it fixes photographic emulsions. In order to study the rate of fixation, a method of determining "clearing time" was first adopted. It is well known that the

clearing time is the time necessary for the turbidity of the silver salt in the emulsion to disappear. Evidence has been produced to indicate that the fixing time is synonymous with the clearing time.^{19, 20} However, Warwick²¹ showed that fixation should be continued for twice the clearing time to be sure of removing all the unreduced silver salts. It is a generally accepted safety measure to fix all photographic emulsions for twice as long as it takes for them to clear if permanence is desired.

Numerous experimenters have used various means of measuring the clearing time of photographic emulsions. An adaptation of the method of C. Welborne Piper²² seemed to give the most reproducible results and it was used in these experiments. With the hope that some day some such method may be standardized, a complete description of the method used in these experiments is given:

The fixing solution to be tested was placed in a shallow glass tray. A sheet of matte-finish, black paper of sufficient size to cover the bottom of the tray was immersed in the fixing solution to provide a black background (paper usually packaged between sheets of cut film was found to be satisfactory for this purpose). A streak or puddle of the fixing solution to be tested was placed on the center of the strip of film to be tested, using a glass rod, and the streak was allowed to remain on the film for approximately one-fourth of the expected clearing time.

When wet film was used, it was difficult to prevent the fixing solution from running over the film, so an alternate method was used; such as immersing one end of the strip or, better still, bending the strip in the form of a horseshoe and immersing the center portion of the strip in the bath for approximately one-fourth of the expected clearing time. Then, the entire strip of film was plunged into the fixing solution and a stop watch was started simultaneously. The strip of film was vigorously shaken when first immersed and was given two or three shakes at ten-second intervals thereafter.

The best method of observing the disappearance of the turbidity of the emulsion was to view the strip of film at a low angle using illumination placed directly above the tray. It also helped to have a dark-colored background on the opposite side of the dish from which the observation was made.

End of Clearing Time

(a) For combinations of films and solutions that produced completely transparent emulsions, the clearing time was taken as that point at which the last trace of turbidity disappeared. If traces of turbidity, which were patently caused by finger marks or contamination, remained after the clear portion of the film had become largely transparent, they were disregarded.

(b) For combinations of films and solutions that failed to give completely transparent emulsions, the clearing time was taken as that point at which the streak or blotch produced by the preliminary treatment with the solution became indistinguishable from the remainder of the emulsion.

The concentration of the fixing bath, the type of emulsion used, the temperature of the fixing bath, and, to a slight extent, the ingredients used in the acid-hardening solution, all influence the rate of clearing. The concentration of the fixing bath has the largest single effect on the clearing time and will be considered first.

Conflicting views on the relationship between clearing time and concentration of sodium thiosulfate have been reported. C. Welborne Piper²² in 1913 concluded that there was an optimum concentration of sodium thiosulfate at which the clearing time was a minimum. Above or below this concentration the clearing time increased. When the data were plotted with the clearing time along

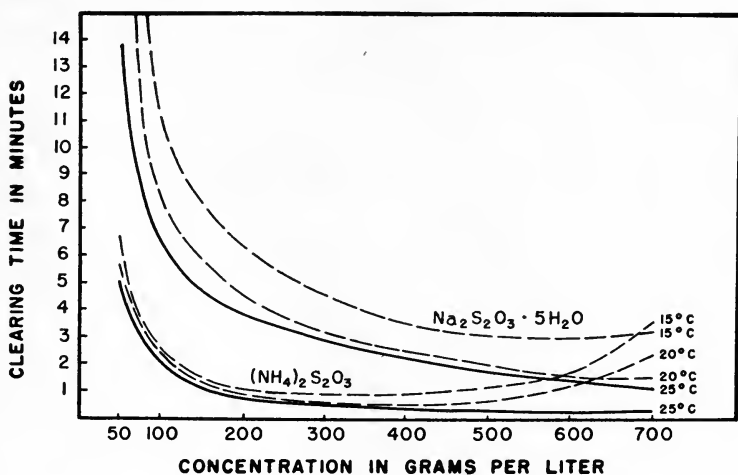


FIG. 2.

the vertical axis and the concentration along the horizontal, a generally broad based, *U*-shaped curve resulted. The bottom of the *U* was the point of most rapid clearing, and it occurred at a concentration of about 40 per cent sodium thiosulfate at 20°C (68°F). Crabtree and Hartt¹⁴ reached the same general conclusion in 1929. In striking contrast to these findings, Hanson²³ recently showed that the clearing time progressively decreased with increases in the concentration of sodium thiosulfate. He found no optimum concentration at which clearing time was at a minimum and offered no explanation of the apparent contradiction between his observations and those of the earlier workers.

We have now found that in the case of ammonium thiosulfate either type of clearing time curve can be obtained, depending upon whether the measurement is made on dry or wet film. Based on our observations, our conclusion is that Piper, and Crabtree and Hartt must have measured clearing time on dry film while Hanson must have used wet film. When a dry emulsion is immersed in a fixing solution, the solution must wet and diffuse into the emulsion before chemical reaction can take place. Dry emulsions placed directly in 40 per cent to 50 per cent sodium thiosulfate solutions do not clear in an hour or more at room temperatures. Wet emulsions placed directly in 40 per cent to 50 per cent sodium thiosulfate solutions do not clear in an hour or more at room temperatures. Wet emulsions similarly treated clear readily. That the more highly concentrated

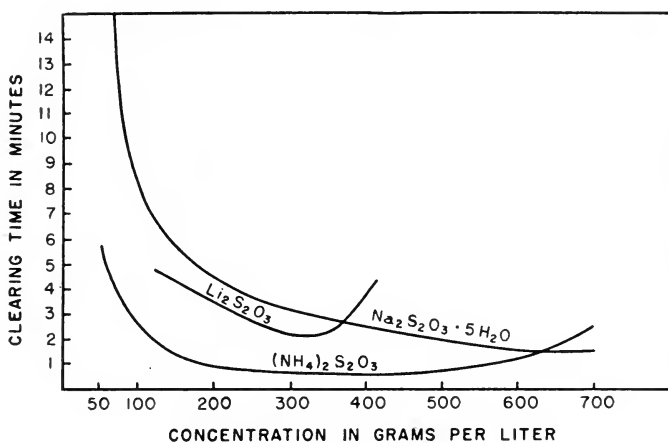


FIG. 3.

solutions do not diffuse into the dry emulsion as rapidly as the more dilute solutions seems entirely reasonable.

In our work we measured the clearing time of wet film, since this gives values of more practical photographic significance.

Fig. 2 shows the clearing times of Super-XX film at various concentrations of both sodium and ammonium thiosulfates. The film was soaked in distilled water for five minutes before each determination was made. The main curves show the clearing times of the two agents at 25°C (77°F). Supplementary curves in broken lines show the clearing times at 20°C (68°F) and 15°C (59°F). Not only is the time of clearing shorter at the higher temperatures, but it will be noted that the retarding action of high concentrations is practically

absent at 25°C (77°F). The wide difference in speed between the action of the sodium and the ammonium thiosulfate is apparent. The time of clearing for the ammonium thiosulfate becomes rapidly less as the concentration is increased up to about 20 per cent. Thereafter, the increased speed is not commensurate with the extra quantities of the agent used. It is apparent that a solution of ammonium thiosulfate containing 200 grams per liter is as rapid in its action as that of a sodium thiosulfate solution containing 700 grams per liter.

Schramm²⁴ has suggested that lithium thiosulfate might give even more rapid clearing action than ammonium thiosulfate. Clearing times were run on solutions of different strengths of lithium thiosulfate, in the same manner as those illustrated in Fig. 2. Fig. 3 shows the clearing times at 20°C (68°F) of Super-XX film at various concentrations for all three thiosulfates. As can be seen, the clearing times of lithium thiosulfate fall between those of the sodium and the ammonium thiosulfates. It is interesting to note that the retarding effect of higher concentrations of lithium thiosulfate on the clearing times is much more pronounced than it is with ammonium thiosulfate.

Experimental determinations of clearing times at widely variant temperatures indicate that temperature is also an important factor affecting the clearing time. An idea of this effect may be had from the fact that a 15 per cent solution of ammonium thiosulfate requires two and one-quarter minutes to clear Super-XX film at 10°C (50°F), but at 60°C (140°F) this same solution clears the emulsion in fifteen seconds.

Various types of emulsions require different fixing times, as indicated by Table III below. The clearing times are given in seconds for a solution of ammonium thiosulfate containing 148 grams per 1000 cc, as compared to a solution of sodium thiosulfate containing 248 grams of the crystalline solid per 1000 cc.

TABLE III

Clearing Time in Seconds of Various Emulsions at 20°C (68°F)

Type of Film	(NH ₄) ₂ S ₂ O ₃	Na ₂ S ₂ O ₃ ·5H ₂ O
Process	13	21
X-ray	35	96
Fast Fine-Grain	50	215
Super-Fast Panchromatic	52	210
Standard Panchromatic	58	238
Orthochromatic	60	240

These two concentrations of the thiosulfates are chemically equivalent. It will be noted that the ammonium thiosulfate clears the film in from one-half to one-quarter the time required by the sodium thiosulfate solution.

Another factor, which might possibly affect the clearing time of emulsions, is the pre-treatment of the emulsion before it reaches the fixing bath. In nearly every case this pre-treatment will include development, which means exposure for a period of several minutes to a solution of strong alkalinity and a rinse in a short stop bath with or without a hardener. Experiments of Sheppard and Mees²⁵ indicated that formalin hardening had no effect on the rate of fixation of photographic film. Experiments by Crabtree and Hartt¹⁴ indicated that excessive quantities of the hardener constituents of a stop bath absorbed into the emulsion would retard fixation. For all practical purposes, when using normal hardening baths, the hardener did not materially affect the time of fixation. One or two simple tests confirmed these statements in our own experiments.

Extensive experiments showed that the amount of absorbed water contained in the emulsion had a large effect on the clearing time. This was especially true of concentrations of thiosulfate higher than those ordinarily used. It did not appear to make any difference whether the film was first soaked in a developer, a sodium carbonate solution, or plain water, as long as the emulsion had been permitted to absorb sufficient water. Experiments on the length of time necessary for the Super-XX emulsion to absorb sufficient water for its clearing time to reach a minimum in any particular concentration of thiosulfate, showed that at 20°C (68°F) the time was approximately three minutes. Therefore, in all clearing time tests, the standard preliminary treatment was to soak the emulsion to be tested in distilled water at 20°C (68°F) for at least five minutes.

Clarity of Fixed Emulsions.—It has been claimed by Dawson²⁶ that ammonium thiosulfate fixing baths produce a completely transparent image as soon as the film is cleared, whereas sodium thiosulfate fixing baths ordinarily leave a haze in the image until the film has been completely washed. We found that *x*-ray films fixed in ammonium thiosulfate solutions containing 200 grams per liter were clearer than those fixed in sodium thiosulfate solutions of this concentration. Below this concentration the differences in clarity were not significant. At concentrations greater than 200 grams per liter, the difference in clarity was more pronounced. When this experi-

ment was repeated, using Super-XX film, little or no difference in clarity could be noticed between the ammonium and sodium thiosulfate solutions until a concentration of 260 grams per liter was reached. Dawson's claim was substantiated in the case of *x*-ray films, but a comparable difference does not seem to exist with Super-XX film.

Reducing Action.—The fact that fresh fixing baths have a definite reducing action on the silver image of a photographic emulsion has been known for some time. Russell and Crabtree²⁷ in 1932 studied the reducing action of fresh fixing baths on the silver image of a photographic emulsion. They concluded that the amount of reduction produced by a given fixing bath was directly proportional to its acidity. Therefore, when using fresh chrome alum baths having high acidity, the amount of reduction became important. However, in ordinary work, except with very fresh potassium alum baths, this reducing action was insignificant. Dawson²⁶ has pointed out that the reducing action of ammonium thiosulfate fixing baths at equal *pH* values was definitely greater than those of sodium thiosulfate fixing baths on *x*-ray film. It also has been reported by J. S. Mertle¹ that experiments with process plates used in lithography have definitely showed that the opacity of the dots can be lessened materially by prolonged treatment in the *ATF-1* fixing bath. Therefore, it is recommended that process films or plates should be allowed to remain in ammonium thiosulfate fixing baths not longer than double their clearing time.

Experiments with photographic papers have shown that the fresh ammonium thiosulfate fixing baths can have a decided reducing action on the images. Ammonium thiosulfate fixing bath formulas, containing 150 grams per liter, appeared to give no noticeable reduction in a 10-minute fixing period. However, formulas using 200 grams per liter, such as *ATF-4* and *ATF-5*, have a marked effect within eight minutes. Therefore, when fixing baths *ATF-4* and *5* are used for photographic paper, it is recommended that the prints should not be allowed to remain in the bath longer than four minutes. The high acidity chrome alum formulas should not be used for photographic paper.

Hardening Properties.—The most important property of any fixing bath, besides its ability to fix emulsions properly without deleterious effects, is its ability to produce satisfactory hardening of the gelatin so that such emulsions may be washed and dried with-

out damage. Aluminum or chromium compounds have been most generally used in acid-hardening fixing baths. An extensive discussion of the action of these two agents and of the theories connected with their hardening action is given by Sheppard, Elliott, and Sweet.¹⁰ Their work showed that the efficiency of the hardening action of the alums was dependent almost entirely on the *pH* of the solution in which they were used. It follows that the ability of the fixing bath to maintain the proper acidity, even with continual additions of alkali carried over from the developer, is a matter of prime importance in the production of serviceable fixing bath formulas.

Measurement of the degree of hardening of any particular bath on a gelatin emulsion is usually made by determining the melting point of the treated emulsion. One of the oldest and most commonly used methods of determining the melting points of gelatin emulsions is described by Crabtree and Hartt.¹⁴ More recently, Woosley and Pankhurst¹⁸ described a method of determining melting points which appeared to us to have greater reproducibility. Instead of determining the melting point or dispersal point of the gelatin emulsion simply by raising the temperature of a water bath in which it was immersed, the emulsion was continually abraded by a slight but fairly constant pressure from a rubber-tipped stirring rod. The melting point determined by this method is defined as the lowest temperature at which this stroking with the rubber-tipped glass rod first produces detachment of the gelatin from the film base. Melting points determined by such a method are several degrees below those determined by the older method, but they are probably more in accordance with the requirements of practice.

In order to determine the effect of various periods of washing and drying upon the melting point of the hardened emulsion, strips of film developed and fixed in the same solutions, at the same time, were given different periods of washing and were allowed to dry for different periods of time. The results indicated that washing periods of from fifteen minutes to 120 minutes and drying periods of from zero to twenty-four hours had practically no effect on the melting point of the gelatin emulsion. Therefore, in most cases, melting point tests were run on film strips either immediately after washing or after a short drying period. It is possible that films dried over a considerable period of time may gain slightly in hardness, but our experiments indicated that melting points run on freshly processed

film and portions of the same film kept for several weeks were only a few degrees different.

In Figs. 4 and 5, the ability of the *ATF-1* and *ATF-2* fixing baths

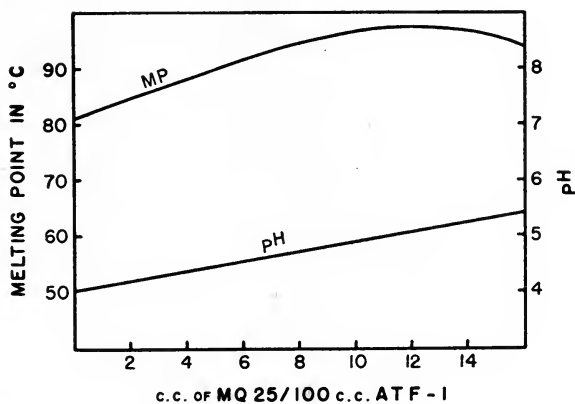


FIG. 4.

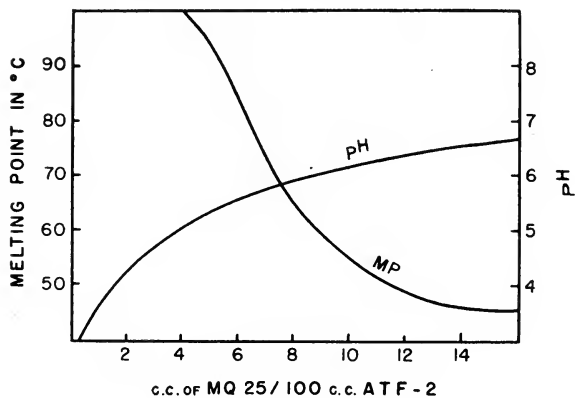


FIG. 5.

to produce hardening when contaminated with varied amounts of *MQ25** developer is illustrated graphically. It will be noted that

**MQ25* Formula:

Metol	1.25 gm	Sodium carbonate, anhyd.	25.00 gm
Sodium sulfite	75.00 gm	Potassium bromide	1.5 gm
Hydroquinone	4.75 gm	Water, enough to make	1 liter

the *ATF-1* formula continues to produce satisfactory hardening even after the *pH* of the bath has attained a value of over 6, whereas, in common with other chrome alum fixing baths, the *ATF-2* formula rapidly loses its hardening action as the *pH* approaches 5. The inability of the unbuffered chrome alum bath to tolerate more than a slight amount of developer contamination is also apparent.

In developing hardeners for ammonium thiosulfate fixing baths, we considered it also desirable for the hardener to have rapid action in order to take advantage of the rapid clearing action of these baths.

Fig. 6 illustrates graphically the speed with which a Super-*XX* emulsion is hardened in the *ATF-1* fixing bath and in the *ATF-2* fixing bath. It is readily apparent that the chromium bath will

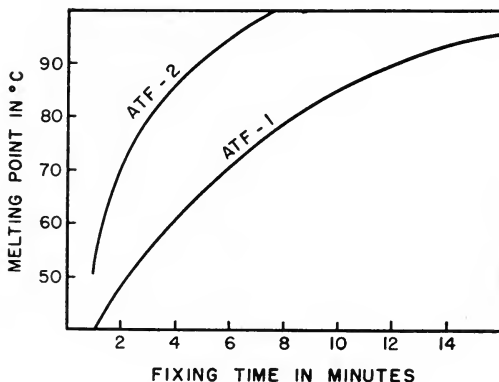


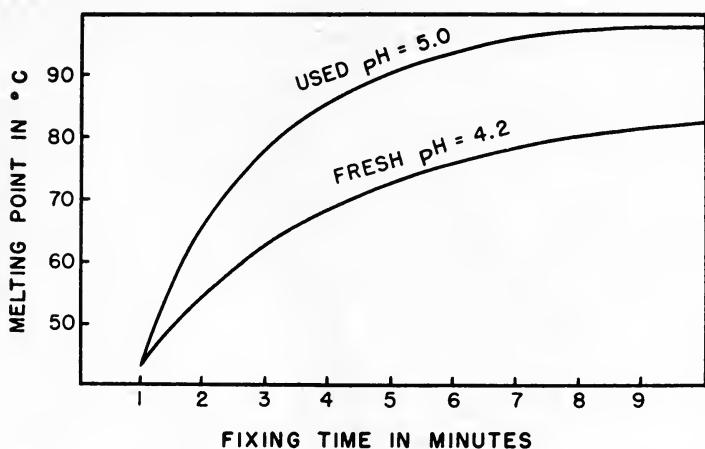
FIG. 6.

give sufficient hardening for the proper handling of the film within one minute, whereas it would probably be advisable, when using the *ATF-1* formula, to allow the film to remain in the bath from 2 to 4 minutes. In general, it appears that aluminum-hardening ammonium thiosulfate fixing baths will give satisfactory hardening within twice the clearing time.

Fig. 7 shows the effect of use on the rapidity of the hardening action of the *ATF-5* fixing bath. Super-*XX* film is hardened more rapidly in a used fixing bath having a *pH* of 5 than in a fresh bath. This is occasioned by the fact that the optimum hardening action of an aluminum alum fixing bath occurs in the range of 4.5 to 5.5 for ammonium thiosulfate fixing baths, so that the rapidity of the action

is not decreased until such a fixing bath is near its exhaustion point. Since the fresh baths have a pH in the neighborhood of 4.2, optimum hardening does not begin until use of the bath has increased its pH to the effective hardening range.

The fact that addition of ammonium salts to sodium thiosulfate fixing baths increases the speed of fixation has been long known. C. Welborne Piper²⁸ in 1914 found that a concentration of 4 per cent ammonium chloride added to a 20 per cent sodium thiosulfate fixing bath gave the optimum reduction in clearing time for the Lumière films he used. Recently, Crabtree, Muehler, and Russell¹³ published a rapid-fixing bath formula, designated *F-7*, using 50



* FIG. 7.

grams of ammonium chloride and 360 grams of sodium thiosulfate per liter. They also suggested the addition of ammonium chloride to regular sodium thiosulfate fixing baths in amounts of 5 per cent for the purpose of increasing the rapidity of action of such baths. They pointed out, however, that additions of ammonium chloride decreased slightly the hardening properties of such baths. Therefore, in connection with the investigation of the hardening properties of the ammonium thiosulfate fixing baths, it was thought worth while to compare the hardening action of a typical ammonium thiosulfate fixing bath with that of the *F-7* fixing bath.

The curves in Fig. 8 represent the clearing times and melting points of strips of Super-XX film that had been developed in *MQ-25*

for four minutes and then fixed for ten minutes each in a 50-cc sample of the fixing bath tested. This procedure was the same as that used in exhaustion tests, which will be explained in detail later. As can be seen from the curves, the hardening properties of the *ATF-1* fixing bath are considerably better than those of the *F-7*. It will also be observed that clearing times of the *F-7*, although short, are not so short as those of the ammonium thiosulfate bath.

Blistering.—Blistering of film is a rather uncommon occurrence when the more modern fixing bath formulas are used. The blistering of emulsions is due to the rapid evolution of carbon dioxide gas from the reaction of the sodium carbonate of the developer with the acid of the fixing bath. If the processing temperature is main-

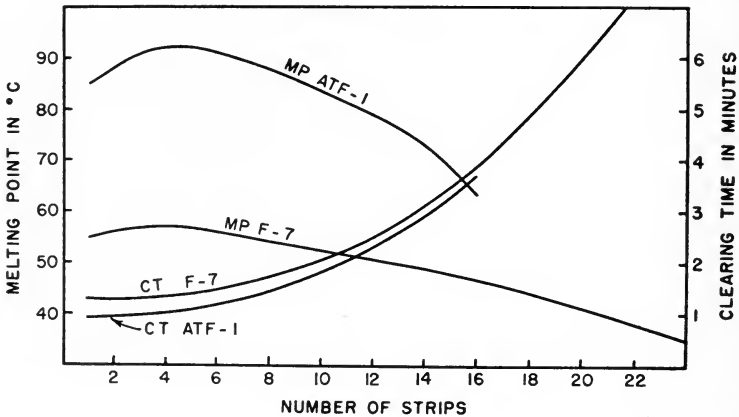


FIG. 8. *

tained at a normal level; if the amount of carbonate in the developer is not excessive; and if the *pH* of the fixing bath in use is not too low, this accidental blistering is very unlikely to occur. In all of our testing of the five fixing baths, even at room temperatures of around 25°C (77°F) and while using the high carbonate *D-19* developer, blistering of the emulsion was never noticed.

Washing.—Extensive comparative experiments between an *F-5* fixing bath and the *ATF-5* fixing bath indicated that the thiosulfate was eliminated from films and papers at approximately the same rate. These experiments were carried out by fixing a 4 × 5-inch sheet of either film or paper in a small photographic tray for a ten-minute period. The fixing bath was drained from the tray and the

sheet of material for thirty seconds and was replaced by a 100-cc portion of distilled water. After thirty seconds of constant agitation, this first wash water was discarded by draining the tray and the material for thirty seconds. Then a second 100-cc portion of distilled water was poured into the tray and, after a one-minute period of constant agitation, this second wash water was drained into a beaker and titrated with 0.1 *N* iodine solution. The third wash water was put into the tray, given constant agitation for two minutes, drained, and titrated. The fourth wash water was allowed to act for four minutes; the fifth wash water for ninety minutes. The last two wash waters were not given constant agitation, but the tray was rocked every few minutes. Each wash water was titrated, and the amount of 0.1 *N* iodine consumed was used as a measure of the amount of thiosulfate removed by each wash water. The rate of removal of the two fixing agents was approximately the same.

Sulfurization.—The length of time a fixing bath can be stored without precipitation of free sulfur is called its sulfurization life. Since modern fixing baths sometimes have sulfurization lives of several months, the usual practice¹⁴ is to store samples of the fixing bath to be tested in glass-stoppered bottles at elevated temperatures. Due to their high acidity, the chrome alum fixing baths *ATF-2* and *ATF-3* sulfurize rapidly. Samples of *ATF-4*, *ATF-5*, *F-5*, and *F-7* were stored, both at room temperature and at 40°C (104°F), and remained free from turbidity for four weeks. When similarly tested, the *ATF-1* fixing bath at 40°C (104°F) showed a precipitate of free sulfur in one week.

Sludging.—The property of a fixing bath to tolerate quantities of alkaline developer without forming a sludge of aluminum sulfite is called the “sludging propensity”; or sometimes, the “developer toleration” of the fixing bath. Since in practice additions of developer to acid-hardening fixing baths are usually made at very slow rates, the common method of carrying out this test has been to add the developer slowly to the fixing bath while constantly stirring, noting the amount of developer which first causes a slight precipitate. Although this method has been used for some time, Wosley and Pankhurst¹⁸ have described the method that we adopted for one type of sludge test. Their definition of the relative sludge life is “the number of cc of developer necessary to cause a permanent opalescence when added to 100 cc of the fixing bath at a rate of about one drop per two seconds while constantly stirring at 65°F.”

The results obtained by applying this test to the fixing baths being compared are set forth in Table IV.

TABLE IV

Relative Sludge Life at 20°C (68°F)

	<i>ATF-1</i>	<i>ATF-4</i>	<i>ATF-5</i>	<i>F-5</i>	<i>F-7</i>
Original pH	4.1	4.1	4.1	4.05	4.1
pH at sludge point	7.1	8.1	7.9	7.8	7.7
cc <i>MQ25</i> per 100 cc bath	80-85	150-200	150-175	150-180	140-175

With this type of test no sludging occurs even at 200 cc of *MQ25* per 100 cc of bath for the chrome alum baths. It will be noted that *ATF-4* and *ATF-5* compare very favorably with the *F-5* and *F-7* baths, whereas the *ATF-1* bath has a lower relative sludge life.

Another method for measuring the relative sludge life of a fixing bath has been used by Crabtree and Hartt,¹⁴ which consists in adding various amounts of developer to equal portions of the fixing baths to be compared and storing these samples at an elevated temperature. The results of this type of test for sludging propensity of the various fixing baths are given in Table V. These results are expressed in the number of cc of *MQ25* developer which were tolerated by 100 cc of a fixing bath at 40°C (104°F) for fifteen days without the development of turbidity.

TABLE V

Relative Sludge Life at 40°C (104°F)

	<i>ATF-1</i>	<i>ATF-4</i>	<i>ATF-5</i>	<i>F-5</i>	<i>F-7</i>
cc of <i>MQ25</i> per 100 cc bath	16	32	32	22	26

By this test for relative sludge life the chrome alum baths *ATF-2* and *ATF-3* failed in a matter of four days. In this length of time a turbidity developed in the chrome alum baths whether the amount of developer added was large or small. Here again, the *ATF-4* and *ATF-5* baths compare favorably with *F-5* and *F-7*, whereas the *ATF-1* bath has a slightly lower tolerance for carried-over developer.

Exhaustion Tests.—Many different methods have been proposed for determining the exhaustion point of fixing baths. One of the oldest and still commonly used axioms is, "Discard the fixing bath when the clearing time of the film being processed becomes twice as long as it was in the fresh fixing bath." Theoretical considerations involved in determining the exhaustion point of a fixing bath were

published by Lumière and Seyewetz²⁹ in 1907. At that time, through a study of the solubility of silver bromide in sodium thiosulfate, they proposed a test for recognizing the moment when a fixing bath should be discarded. This test was the well known one of exposing a drop of the fixing bath on a filter paper to strong light and humid air. If this spot discolored, the fixing bath should be discarded.

Another test of similar nature (depending on the amount of dissolved silver in the fixing bath) was attributed to Bayer by Clerk.³⁰ This test consisted of adding 10 cc of a 4 per cent solution of potassium bromide to 100 cc of the bath under test and noting the formation of a permanent yellow precipitate which was assumed to indicate exhaustion of the bath.

Lumière and Seyewetz²⁹ in 1924 revised their ideas on the exhaustion point of fixing baths and proposed another test that is probably as practical as one can use for determining the presence of silver salts in a finished emulsion. This test used a drop of sodium sulfide solution (0.2 per cent) placed directly on the fixed and washed emulsion under test. A discoloration of the emulsion connoted the use of an exhausted fixing bath.

None of these tests is of practical value, however, if the fixing bath loses its hardening properties before it has reached such a state of exhaustion as to be discernible by them. Furthermore, in many processing installations where machine processing is used, the increased time of fixation becomes the limiting factor that determines the useful life of the fixing bath.

Rather than depend upon any one or two methods of measuring the exhaustion point of a fixing bath, our tests were designed to show the melting point (hardening action), the clearing time, and the change in pH of each bath during exhaustion. The spot tests on filter paper were made on each bath, but are not shown in graphic form. Experiments with the method of treating the fixed film with sodium sulfide solution did not give conclusive evidence of the exhaustion point of the bath; so they were not continued throughout the series.

Exhaustion tests, at best, are comparative only when done on a very large scale and under practical working conditions. Therefore, we do not feel that the results of the experimental exhaustion tests can be applied directly to practical usage in determining the amount of film that could be satisfactorily processed in any partic-

ular fixing bath. The same process and technique were used on each bath and every precaution was taken to make the tests comparative. The following is a brief outline of the method of running the exhaustion tests:

Eight- by ten-inch sheets of Super-XX cut film were given a flash exposure through a slit negative so that approximately $\frac{1}{3}$ of the surface of the film was exposed. This sheet was then cut into 1×8 -inch strips having an exposed portion in the center of each strip. Only 50 cc of the fixing bath to be tested was used for each exhaustion test. Each strip was developed for four minutes in MQ25 developer at 20°C (68°F). Then the strip was drained for five seconds and immersed in the fixing bath at 20°C (68°F) after having the spot of fixing

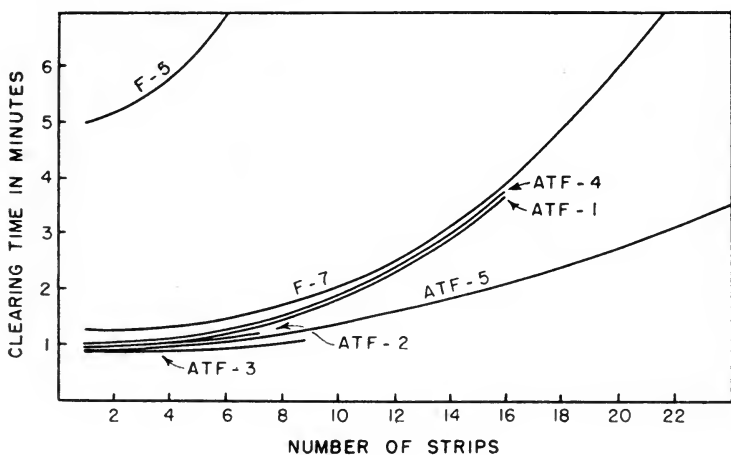


FIG. 9.

solution applied to it, as described under clearing time tests. The clearing time was noted and the strip was allowed to remain in the fixing bath for a total of ten minutes in each case.

Then the strip was drained for five seconds and washed for thirty minutes in water at 20°C (68°F). After washing, the melting point test, as described under hardening properties, was applied to each strip. Strip after strip was processed in the above manner using the same 50 cc of fixing bath until its pH indicated that the bath was exhausted. At the beginning of the test and after every second strip thereafter, a pH was run on the fixing bath. All pH measurements were made on a Leeds and Northup Low Sodium Glass Electrode.

The results of the comparative exhaustion tests made on these fixing baths are shown in graphs, Figs. 9, 10, and 11. As may be

seen from Fig. 9, the *F-5* is the only formula not showing rapid clearing action. In each case the ammonium thiosulfate fixing baths give somewhat more rapid fixation and continued to give this rapid action longer than does the combination of sodium thiosulfate and ammonium chloride. If the speed of fixation is used as the limiting factor in the useful life of a fixing bath, it can be seen that *ATF-5* should give the longest service life. *ATF-1*, *ATF-4*, and *F-7* should give practically equivalent service life and, of course, the chrome alum baths, *ATF-2* and *ATF-3*, would fail on other accounts.

Fig. 10 gives a general idea of the hardening properties of each of these fixing baths during exhaustion. The chrome alum baths give

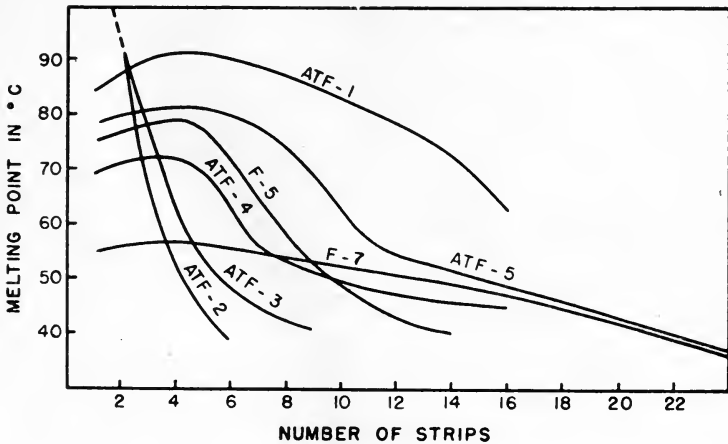


FIG. 10.

excellent hardening for the first few strips, but rapidly lose their hardening power, as their acidity is lost through neutralization with carried-over alkali from the developer. The *ATF-1* containing the aluminum chloride hardening agent gives much better hardening action than any of the other baths. The *ATF-4* and *ATF-5* give hardening action comparable to that obtained with the *F-5* formula. As will be noted, the hardening action of the ammonium chloride *F-7* formula is less than that of the other baths tested.

Since the rate at which the developer was carried over into the fixing bath was practically constant, and since the amount and type

of acidity used in all the baths except the chrome alum baths were the same, the pH of these baths during exhaustion would be expected to rise at practically the same rate. As can be seen in Fig. 11, the baths decreased in acidity at about the same rate. Naturally, the lack of any buffering substance in the chrome alum baths gives them a low tolerance for carried-over alkali and the pH of these two baths increased more rapidly.

The spot test was made during the exhaustion of each of these baths by placing one drop of the fixing bath on a piece of white blotting paper after each strip was fixed. At the conclusion of the tests, these spots were exposed to the direct rays of a mercury vapor

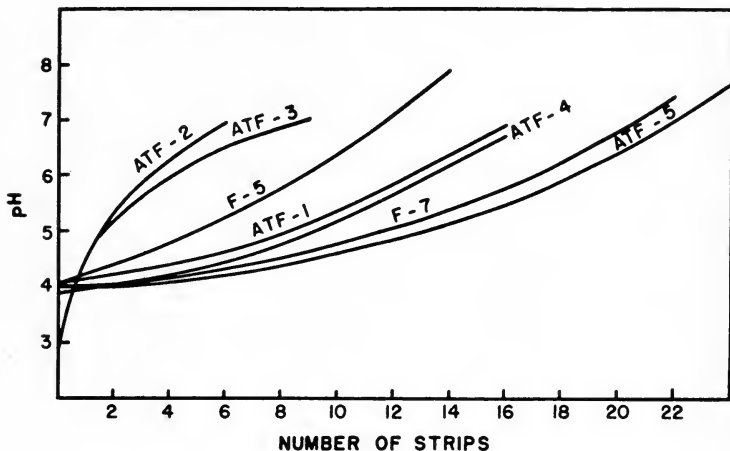


FIG. 11.

lamp for a period of four hours. This exposure was found to be sufficient to develop all the color that would eventually be developed even by a prolonged exposure. By choosing the last spot that did not develop color with this test, a comparison of the power of the fixing bath for holding dissolved silver in a non-staining form can be obtained.

The results of these spot tests were somewhat erratic and their meaning is not entirely clear, since it is possible that fixing baths containing enough silver to show stain by this test would still render the silver salts in an emulsion sufficiently soluble to be completely washed out. The apparently anomalous results of these tests are shown as follows:

- ATF-1 showed color after the 10th strip.
ATF-2 showed color after the 2nd strip.
ATF-3 showed no color after the 9th strip.
ATF-4 showed color after the 8th strip.
ATF-5 showed color after the 12th strip.
F-5 showed color after the 5th strip.
F-7 showed color after the 18th strip.

Although the service life of any given fixing bath depends largely on the method used in determining its exhaustion point, it does appear from these tests that any of the ammonium thiosulfate fixing baths can be expected to give equal or better service life than commonly used sodium thiosulfate baths.

ACKNOWLEDGMENT

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THE MOTION PICTURE IN THE SERVICE OF THE ARMY AIR FORCES*

LAWRENCE CARR**

In 1937 the Army Air Forces started its training film program. Since that time millions of feet of film have passed through hundreds of projectors and have been seen by hundreds of thousands of Air Force soldiers from the lowest yard bird to the brassiest brass hat.

Our training film program is designed to provide, as quickly as possible, needed materials of instruction and, at the same time, to avoid unnecessary duplication of similar materials being produced by the Navy, the ground forces, the British, and other governmental agencies.

We have drawn upon the services of many specialists in the motion picture industry to work closely with our specialists in the Air Forces. By effecting such combinations of talents, it has been possible to produce training films of outstanding instructional effectiveness. Here I would like to pay tribute to the many individuals who have given so generously of their professional skills and equipment in the development of Army Air Forces training films. I know particularly of the fine work done by Col. Keighley of the AAF, and Maj. Cowling whom you all know. I believe he has been for some years an officer of this organization.

It is General Arnold's wish that the training film program be integrated with the instructional courses being given within the Air Forces. Courses of study are analyzed to find subject matter that can be presented to good advantage in motion picture form. Continuous contacts are maintained with instructors in this country and abroad so that the training problems may be considered from the standpoint of instructor and trainee.

There has existed a need for a central agency within the Army Air Forces to coördinate the development of the training film program. Recognition of this is one of the reasons why the Training Aids Division of the Army Air Forces has been organized. Our offices will

* Presented at the 1943 Spring Meeting at New York.

** Colonel, Training Aids Division, Army Air Forces, Washington.

be maintained at One Park Avenue, New York City, after May 20, 1943. The training film section of Training Aids is staffed with officers and enlisted personnel familiar with the motion picture industry.

Our problems with training films can be divided roughly into three parts: they are concerned with production, distribution, and proper utilization of films.

There are hundreds of films used in Air Forces instruction, covering such subjects as flight instruction, gunnery, bombardment, aircraft detection and recognition, navigation, intelligence procedures, and many other allied subjects, as well as films about engines, parachutes, brakes, instruments, photography, communication systems, and inspection procedures.

There are more technical than tactical films due to the relative stability of these subjects. With the changing or conflicting doctrines of tactics, such film materials sometimes become obsolete before they are completed.

General rules in deciding what films are to be produced are: first, the relative importance of the subject to the training activities; second, the suitability of the subject matter; and third, the production requirements with reference to military personnel, materials, and equipment.

After approval for production a study is made to determine what elements of the sound motion picture should be employed to simplify the concepts involved. Will it be animation to clarify abstractions or complex movements, or will it be ultra-rapid photography to study opaque objects and movements? Maybe photomicrography is needed to reveal material stress and strain. Color is important, of course, for medical and camouflage subjects.

Production units are maintained at Wright Field, Dayton, Ohio, for the production of training films dealing with mechanical and electrical equipment. Wright Field is the heart of the aeronautical research activities of the Air Forces. Other facilities are at Culver City, California, where the AAF first motion picture unit is located. This organization has recently produced such films as *Learn and Live*, *Swim and Live*, *How to Fly the B-26*, the film you will see upon the completion of this talk, *Straight and Level Flights* and *The Identification of the Jap Zero*.

Another important source of films is the aircraft equipment manufacturers. They prepare, through their own facilities and after coordination with training aids, films on the installation, operation, and servicing of their equipment.

After an Army Air Forces training film has been completed and has the approval of qualified technical authorities, it is released for distribution to Army Air Forces stations both at home and abroad. Distribution needs are determined through the training sections of the various Commands and Air Forces. A composite order is then given to commercial laboratories for the needed number of prints. The prints are sent directly from the laboratory to the using stations. Sixteen-millimeter prints are used almost exclusively. At present, an average of about 250 prints of each Army Air Forces training film is distributed. At first thought, this number may seem great, but we consider training films and reference materials similar to field manuals, books, technical orders and other publications, and believe these films should be available for use from local station libraries. If only one trainee were to get one idea that would prevent one casualty or destruction of one airplane, the cost of the film would be entirely liquidated.

There are techniques for the use of training films as there are for their production. We are preparing instructor's manuals for Air Force films. These manuals include a detailed description of the film, suggestions for its use, reading references, and objective test questions.

The instructor can make or break the usefulness of a film. The idea that large groups can be exposed to training films and come away with a mastery of the content is erroneous, and it is one of the aims of the Training Aids Division to point this out to users. Then, too, the use of films unrelated to the instructional problem at hand is discouraged; likewise, the showing of more than one film of ten or fifteen minutes in any one period. Films requiring longer projection periods are shown in short sequences. Particular attention must be paid to the physical conditions under which films are shown. It is, of course, deadly to show films immediately after eating or in a room inadequately darkened and ventilated.

In order that the same degree of supervision and coördination which is realized in the preparation and production of training films may be exercised in their use, especially trained officers are assigned to help Army Air Forces stations obtain training film materials suited to their particular needs.

We are firmly convinced that by carefully planning the *production*, *distribution*, and *use* of training films, the value inherent in the program can be made to contribute to the successful prosecution of the war effort.

A COMPACT PRODUCTION UNIT FOR SPECIALIZED FILM*

O. W. HUNGERFORD**

Summary.—This paper outlines a few short cuts in the use of 16-mm film for specialized film production with a minimum of personnel. Certain features of the setup have reduced man-hours to a minimum and have made a compact, yet thoroughly efficient, unit for the production of secret and timely subjects.

The war has brought about many changes and new ideas. Among these was the overnight recognition of the sound motion picture as an efficient medium for training and for presenting facts and data in predigested form. While much has been written about the large-scale training film production programs that are under way, little has been said about the small, yet complete and self-contained production units whose purpose it is to present facts and data in most concise form. This paper will outline such a production unit.

For security and related reasons, it is usually essential that the operating personnel of such units be kept at an absolute minimum, yet the finished product must be one of highest technical quality. From the standpoint of equipment, a requirement of this kind automatically dictates 16-mm professional machinery; it also dictates extreme versatility in the various persons needed to operate this equipment. In such an organization it is not uncommon that each person will be able to act as cameraman, sound recordist, film editor, special-effects man, printer, and even projectionist as the need may arise. In other words, the members of the staff are capable of "doubling in brass." It is this ability together with the reliability, simplicity, and precision of the machinery chosen that makes the results possible.

CAMERA EQUIPMENT

The camera equipment includes a Maurer professional sound camera for studio and general tripod work. This camera has pilot-pin

* Presented at the 1943 Spring Meeting at New York.

** Washington, D. C.

registration and has the pull-down claw located right at the base of the picture aperture, eliminating that difficulty so common to the magazine-chamber type of camera, frame line shift. This camera can be wound back for double-exposure effect and for lap dissolve.

For studio work it is especially convenient that all lenses supplied for it have been standardized at the SMPE standard distance between the image on the film surface and the mounting shoulder of the lens. All three lens openings in the turret have been standardized at this standard distance. Any standardized lens can be placed in any lens hole. It will focus perfectly in all three. It is interesting to note that as much as three to five thousandths of an inch has to be taken off the lens shoulder to standardize the lens. This extra allowance is left on the lens mount by the lens manufacturer because the film in the usual loose-gate camera bellies away from the lens by approximately this distance. We have also adapted this camera to a stop-motion device for use on a title stand.

The animation stand is equipped with an Eastman Ciné-Special camera adapted to animation by the installation of a calibrated movement of the shutter so that accurate dissolves may be obtained up to 64 frames. This camera is also equipped with a stop-motion motor for either forward or reverse motion, and a direct frame-reading counter that is reversible so that regardless of the direction of travel of the film the counter may be read forward. We use this camera on the technique known as "scratch-off" which we call our "3-2 method." This is simply running the camera backward three frames, then twice forward taking the picture on the second forward motion. In this way we are always able to maintain the same frame line. The effect stand for animation while quite simple is capable of almost any type of action requiring little time in man-hours of operation.

We have set up a standard for our Graphic Division for cell animation with two standard sizes of cells known as our *A* cell, which is $10 \times 12\frac{1}{2}$ inches, and our *B* cell, which is 20×25 inches. These cells are punched with a three-hole punch, the center hole being $\frac{1}{4}$ inch round and the two side pins being $\frac{1}{8}$ inch wide and approximately $\frac{1}{2}$ inch long, spaced 4 inches from the center pin. This size of punching has been adopted by the Navy Photo-Science Laboratory as their standard and for convenience we have also adopted it. A great deal of animation work is also carried on in the old but very often forgotten technique of the cardboard cut-out

model and its counterpart. We have found that this type of procedure speeds up certain animation technique. Approximately 90 per cent of our work deals with animation, and almost 100 per cent of our animation is shot on Kodachrome Type *A* using C. P. bulbs for illumination.

SOUND EQUIPMENT

It is in this department that equipment flexibility and compactness are evident. The basis of our 16-mm recording equipment is a Maurer Model *D* Sound Recorder with the usual noise-reduction equipment. The amplification equipment is rack-mounted with jumping-plug contacts for immediately locating any difficulty that might arise in the equipment. The mixing equipment has an 8-channel input with four active lines. These are permanently contact-jumped from two microphone inputs and two turntable pick-ups. The amplification equipment is set up for film recording, disk recording or re-recording from either disk or film. The disk reproducing equipment is designed to operate at either 33 or 78 rpm. The pick-ups are Western Electric 9A which may be used for either hill-and-dale or lateral recordings. The disk recorder is a Presto which is suitable for either 33 or 78-rpm operation. The film-phonograph equipment consists of two 35-mm film-phonographs and one Maurer 16-mm film-phonograph. This latter equipment has proved to be a reliable and useful machine for many purposes other than re-recording. Very often it is necessary to check the quality of commercially produced prints. This is quite simple as the system has a consistent and very low noise-level and the frequency characteristics of the channel remain the same from day to day. Our projection equipment consists of a Bell & Howell 750-watt projector that we have rebuilt to hold a 1000-watt bulb, and in which we have installed a special preamplifier so that its output may be fed directly into our rack-amplifier for quality reproduction. We are now using a Jensen coaxial wide-range loud-speaker for reproduction with this system. At some later date we hope to install a good two-way reproducer for this channel, such as a Jensen Type *E*. When one becomes accustomed to a system of this sort the use of a conventional projector to reproduce, for instance, a Kodachrome duplicate is rather a blow. Such an arrangement as ours makes it very easy to discriminate between good and bad prints.

EDITING AND EDITING EQUIPMENT

Since most of the fact and data films are built to order, so to speak, very little editing is necessary. Often the sound is made prior to the actual shooting of animation. Therefore the animation action can be accurately timed to the voice. In a composite picture in which we use both live acting or clip shots with animation and occasionally a live synchronized shot, the film is recorded after the assembly process. Since these films are made with the intention of being informative rather than entertaining or "arty," editing of them is relatively a simple job. It must be so, for if the shots were complicated by all sorts of angles, crosscuts, sound-effects, *etc.*, this set-up would defeat its purpose. If organizations of this kind were to think of individualism, which might be called the niceties, of technical production, we would be compelled to set the idea aside owing to the unwarranted diversion of man-hours required for this type of "arty" production.

In conclusion, let me leave this thought with you: while major emphasis must be placed on the large training film project using a great many specialists who need no skill beyond their own particular field, small, compact, highly versatile production teams skilled in all of the essential elements of production make up the personality of these "facts-and-figures" units that are doing their bit very quietly in this war. The nature of the material being portrayed in such films must remain a military secret. Their importance, however, can not be overlooked.

DISCUSSION OF INDUSTRY PROBLEMS*

ED KUYKENDALL**

I am delighted to be able to participate in the annual get-together meeting of such able men who constitute the Society of Motion Picture Engineers. You, gentlemen, are a most vital part of a great industry, an industry that has made tremendous progress over a period of years. You, who have contributed so much to the forward movement of the motion picture industry, are to be congratulated not only for your ability but for your complete determination to move forward and better the all-round development of the motion picture.

The Motion Picture Theatre Owners of America, which is the largest and oldest trade association, has the same interests at heart as you engineers—the development of the industry; that they through their theaters can best and most intelligently serve the public which, after all, is entitled to nothing less.

Over a period of years I have watched the growth and accomplishments of your organization. You have gone forward every minute of the time. The marks of your accomplishments are definitely visible in and about the theaters in this good old U. S. A. You have made it possible for us, the theater owners, to keep abreast of the times—modern times, if you please. You have, in your efforts, made it possible for our theaters to be emblems of modern progressiveness, and as the public, as well as theater management, walk into places of amusement the results of your ingenuity and hard work can be seen readily from all sides. It gives me great personal satisfaction to realize that the theater owner is exploiting your brain child to the fullest.

Still, the theater has a long way to go in progressive development; so far to go yet that we are hesitant in looking down the road with its many curves and bad crossings. But together, arm in arm, we

* Presented at the 1943 Spring Meeting at New York.

** President, Motion Picture Theatre Owners of America.

will continue the forward march of development and progress which the public will surely recognize and show their appreciation at the old box-office.

The all-out war in which we are now engaged has had its hard touch on motion pictures. Many of us are not too happy with the results of government regulation. Many of us will undoubtedly say we would have done this and that differently. Many times I am confused and wonder what it will lead to, but as I sit down and take inventory of the general picture, it seems to me that we, as an industry, have suffered less than most other businesses.

The MPTOA was the first to emphasize the necessity of keeping the theaters open during the stress of war, regardless of hardships and regulations. This is our first duty to the public—we can accept no other attitude. Motion picture entertainment is essential to the levelness of our war-conscious minds.

In selling War Bonds, doing relief work, and conducting general patriotic efforts, we put forth every possible effort, and the results have been most gratifying. We are proud of this work, but it is no more than we should do as good Americans. In fact, it is as little as we should do. My slogan has been, "The most we can do, is the least we should do." I am no believer in using what we have done in our effort to get governmental consideration, but I am all out in making every possible fight to get what justly belongs to us in this confused and hurried world. It is my belief that we should fight to the limit any attempt or thought to pass us by. We owe that to those who have invested all they possess in our industry, and fight we will for our rights—nothing more, nothing less.

Adapting theaters to wartime restrictions is a matter of vital importance not only to theater owners, but to you of the Engineers. In this day of priorities over almost everything, we can not continue on the old basis, but must accept the all-out war theme and learn to do without certain materials in this emergency. You of the Engineers, and we of the theater, must use our ingenuity to continue operations of our theaters, maybe under restrictions, probably with hardships, but do it we will. But, while we are doing this, we are learning many things that will stay with us long after we have knocked hell out of the Axis!

I can not put too much faith in the return of former employees. In my mind, our industry will never be classified as essential to the war effort, but we have not been declared non-essential. We are in

the twilight zone, and our industry is being judged now on a purely individual basis. So it seems like wishful thinking to sit by and hope that former, gifted employees will be sent back to us to resume important work before this fight to the death is over. So let us who are still on the job work harder as individuals: improvise, create, train women, use older men. We, as an industry, do not want to do anything less than our full part in this war.

It is my opinion that the War Activities Committee should be given every possible support by this entire industry. The MPTOA has cooperated with this committee as individuals, and not as an organization. This precludes exhibitor politics. We, who have been placed on this committee, are proud to serve with it, and we believe that the War Activities Committee is the only one that could, and has, functioned for the entire industry.

I have noted criticism from one source about too much flag waving in the theaters. I go on record, personally, as not agreeing with this thought. I believe it is our duty as an industry to see to it that our beloved flag is waved in any and all places. It inspires confidence, gives us a concrete encouragement: an emblem of the American way of life, may it ever wave, and may we, as an industry, leave nothing undone to insure that its waving continues.

I like the name of your organization, "Engineers," meaning planners, devisers, creators, progressive thinkers, carrying on for the whole industry; and the engineers are vital parts of this war effort outside this industry.

We will continue to have our industry worries. We will continue to feel as an industry, and as individuals, that we are not getting our just dues during the stress of war. But let's keep mindful of the fact that it's because of war, and that we must keep ourselves more on the alert to protect our fair interest. It means more work for all of us, but that's no more than we can expect under present conditions.

There are many things, technically and otherwise, I could have discussed with you. All are important and cover many of your varied activities, but time prohibits and this is no place for a speech.

But if, in winning this war, we lose sight of the American principles and way of life, we have gained very little, and would be very unhappy after it was all over. So you and I, as Americans first, and an industry afterward, have a big job before us which we accept with the full importance of its meaning.

It is regrettable that there are quite a few among us who have

allowed the dollar mark to obscure their vision of the future and their obligation to America. They are blinded by the collection of more dollars, and are prone to allow themselves to see only the monetary gains of immediate days. But I warn them: stormy days are ahead for such minds; fairness will be forced on them whether they like it or not. They may find that their immediate financial advantages may be snatched away from them as there can be only one way for us to conduct ourselves: fairness in our relations with each other and patriotic and wholehearted effort for our government. It's the one and only way you and I can hope to be happy and satisfied with ourselves, and really enjoy, personally, what we are doing.

Let's you and I—all of us—keep our balance, continue to work harder and harder for a continuance of our present way of life; allow nothing, or anything, or anybody, to change our course, that you, the Society of Motion Picture Engineers, and we, The Motion Picture Theatre Owners of America, can walk together down the highway of life with the collective knowledge that we did our part, honestly, sincerely, and can look the boys full in the face on their return, knowing that we, too, have done our part as Americans.

SOME SUGGESTED STANDARDS FOR DIRECT 16-MM PRODUCTION*

LLOYD THOMPSON**

Summary.—An increase in the use of direct 16-mm production makes it desirable that certain standards be set up in order that all producers be able to follow definite procedures. If such standards can be agreed upon it will make it much easier for the producer to do his work and train his help. It will allow the equipment manufacturer to produce better machines to handle 16-mm. It will allow the laboratories to give better prints with a minimum of delay and a minimum of error. The standards that are suggested should be studied closely by those interested and suggestions made.

The increased use of direct production of 16-mm film for both sound and photography makes it highly desirable that certain standards be adopted covering the correct procedures to be used. As long as only a few persons or companies were producing direct 16-mm films, standards were not too important because procedures were used that were found by experience to be satisfactory. However, when a large number of persons or companies start using 16-mm film for commercial exhibition, it becomes important that certain standards be adopted. Unless this is done, it will be difficult to find technicians who are capable of working with different companies and almost impossible for the producers to secure good laboratory service, and the equipment manufacturers will be unable to build any sort of professional equipment that will satisfy any great number of users.

Before any standards are adopted, however, it is necessary to find out what is needed and what experience has shown will work. It is always hard for a new industry to set standards because improvements are constantly being made. Today's standard may be obsolete tomorrow. All of us can remember the beginning of radio and the development that has since taken place. Today one might say that the standards are set, but frequency modulation will probably demand new standards. Therefore, any standards proposed in this paper

* Presented at the 1943 Spring Meeting at New York.

** The Calvin Co., Kansas City, Mo.

should probably come under the name of Recommended Practices, but there must be a beginning.

Direct 16-mm production, to be successful, depends upon good laboratory service. There are several organizations with reputations for doing good laboratory work, but even these concerns are not in complete agreement as regards processing methods.

The problem of emulsion position has been previously discussed in the JOURNAL¹ and has been well covered. Two standards are being used today: The emulsion may face either the light-source or the lens. As far as picture position is concerned, one is as good as the other, because the lens may be manually focused for either emulsion position. However, sound is played often on a projector that does not allow focusing of the sound-track, and this can result in a difference in sound quality depending upon the position of the emulsion with respect to the lens. I say there *can* be a difference because most persons will not be able to tell whether the sound-track is in or out of focus as they listen to a large number of the prints being distributed today. On a really good sound print there is a difference, but if the sound-track is really good it will give satisfactory reproduction on an average projector without the focusing arrangement.

Some producers and some editors produce pictures with large numbers of stock shots; this practice is likely to cause trouble if both original reversal films and prints are used. The producer and editor should familiarize themselves with the emulsion position and set their own working standards. Recently I saw an original 16-mm Kodachrome sent in for printing. The photography contained film made on a silent stock and 16-mm sound stock, which is all right. There were 16-mm sound leaders on both ends of the photography. This was also all right, except that the leader on one end was spliced with the sprocket-holes on one side and the other leader had the sprocket-holes on the other side. The editor said he did not know which side he was supposed to use so he used both sides!

The suggested recommended practice: when using the double system, shoot the picture on stock perforated on both sides. Follow this procedure all the way through. If stock shots are used, they should be on this type of stock if possible. If sound stock must be used, be sure it can be printed. (A standard 16-mm reduction sound-print can be cut into an original reversal film with emulsion positions the same and should go through any of the printers being used today.)

Original pictures and sound-tracks coming into a laboratory for printing are the most variable things imaginable. We have our own

standards for attaching leaders to original film for printing, and we shall be glad to send them to anyone who is interested. We have had some difficulty in getting people to follow them and have even been told that they are not correct, but they have been checked a number of times and we are certain of their validity. We have suggested that identification and synchronizing marks be placed upon both ends of the photograph and sound-track reels because all laboratories do not print from the same end. Since 16-mm printers are not standardized, this is probably the only procedure that can be recommended. Fig. 1 shows a suggested recommended practice.

The standard leader developed for 35-mm film is used by some producers for their 16-mm originals. We are opposed to this practice because in the field operators will often project the numbers on the screen at the beginning of the picture. For good presentation plain, marked leaders should be spliced to each new reel.

As a suggested recommended practice a leader four or five feet in length, such as the reversal laboratories use on amateur reversal prints, is proposed.

If there is anything more unstandardized than leaders, it is the light-change punch. We frequently receive originals having two or three sets of light-change punches, and as a rule none of these will work on our printers.

We have no suggested recommended practice for this. The only suggestion we can offer is to set up some sort of standard, and in time most of the laboratories will probably conform to it. It will also give printer manufacturers a basis upon which to work.

While it is probably not the duty of the Society to set up standards for the emulsions to be used for certain jobs, there are probably many who are trying to do 16-mm production for the first time who would welcome some sort of suggestions. Over a period of years we have worked with many who were trying to make their own pictures, and there have been times when they failed simply because they used the wrong type of emulsion. We have found people trying to shoot contrasty titles on blue-base negative stock instead of using a high-contrast positive film.

While certain types of 16-mm film on the market can be developed as either negative or reversal, most types of negative film will not "reverse" successfully. Nevertheless certain persons still persist in trying.

For several years the emulsion makers have been selling 16-mm

sound-recording film that is definitely superior to positive film, but a few persons still try to use ordinary positive stock and others wonder why their *dupe negatives* do not turn out well when they try to make them on positive film.

In suggesting certain emulsions for specific purposes it should be borne in mind that the list is subject to change. It is fairly standard procedure for 16-mm producers to shoot their original photography on either black-and-white reversal film or on color-film. (There are some cases where color-film is used entirely, even when black-and-white prints are wanted.) The following emulsions are suggested:

Black-and-White Photography

Original.—Standard-brand reversal film or color-film. The brand and type must be decided upon by the individual. (For procedure see reference 2.)

Titles.—High-contrast positive film for cheap titles, but for professional titles reversal film with the proper art work.

Work Prints.—Reversal prints on positive film, yellow-dyed sound-recording stock (perforated on both sides), or reversal duplicating film. The positive film is cheaper, and will usually serve the purpose.

Release Prints.—Reversal duplicates made on reversal duplicating film for first prints, or for only a few prints. Dupe negatives should be used for a large number of prints and should be made on panchromatic fine-grain duplicating negative. Positive prints from duplicate negatives are best when made on fine-grain positive film.

Color Photography

Original.—Standard-brand reversal color-film such as Kodachrome or Ansco Color. Mazda-light type for Mazda lights, and daylight-type for daylight. (Some prefer the Mazda type with filters for exteriors.)

Work Prints.—Same as for work-prints from original black-and-white photography, unless the editor feels he must use color work-prints, in which case a regular color release-print is made.

Release Prints.—(a) Color: Made on Kodachrome duplicating film, or equivalent. (b) Black-and-white: Follow same procedure as with black-and-white dupe negatives. If black-and-white reversal prints are wanted it is best to use a duplicating film that is not color-blind, although it is more costly.

Sound

Original.—Use a 16-mm sound-recording emulsion made especially for the purpose.

Prints of Sound Only.—Fine grained positive film.

We offer the above as recommended practice for correct 16-mm production, and if the producer will follow these suggestions he can not go far wrong as 16-mm production is done at the present time.

There have been a number of direct 16-mm productions made where no work-print was used during the editing process, but as more

persons become involved in the production of a picture, the more necessary it becomes that the first editing be done with work-prints. One serious difficulty in using 16-mm work-prints is that there has been no standard method of edge-numbering originals and work-prints so that the two can be easily matched.

For several years the Society has been discussing 16-mm edge-numbering, and a Recommended Practice was finally set up. This is all well and good, except for the fact that edge-numbered films are available only on special order, and a number of emulsions are on the market that must be used in direct 16-mm production that are not available with edge-numbers under any condition.

Some time ago I recommended to the Society that all 16-mm reversal and sound-films be edge-numbered if the system were to work out successfully for 16-mm production. However, because of certain manufacturing difficulties it is not practicable to edge-number all 16-mm reversal film because there is no need for edge-numbering most amateur films. For that reason I am now going to change my recommendation. Since it seems to be impossible to get all 16-mm producers to place special orders for edge-numbered film and use no other kind of stock, it is recommended that

when work-prints are made of the originals, the original photography and work-print be numbered by a machine as is done in 35-mm practice.

The work-prints can first be made, then the edge-numbers be put on the work-print to synchronize with the edge-numbering on the original developed photography. These numbers can be printed also on the sound-track. The producer is thus relieved of the necessity of using edge-numbered film for his originals. Unfortunately we know of no one at the present time who can offer this service, but we have investigated its possibilities and believed that before long such a service will be offered.

There are many kinds of work-prints. Some have used regular black-and-white reversal prints; others have had full-color prints made from their color photography; and some work-prints have been made as negatives after they have been printed on positive film. Since most persons do not want to pay any more than is necessary for work-prints, we have found that work-prints made on some cheap emulsions such as ordinary positive film, and then reversed, give very satisfactory results for most purposes. Work-prints from color-film made in this way are also satisfactory.

We therefore suggest the following recommended practice: Black-and-white work-prints from original black-and-white photography or color-film to be made on positive film and reversal-processed where the minimum amount is to be spent. If better-quality work-prints are desired, use regular reversal prints for black-and-white or color or color-prints for color photography.

Many who are making direct 16-mm pictures for the first time do not seem to realize the importance of securing the proper density for their original sound-tracks or, if they do, they seem unable to give the proper exposure to their film in order to realize this density. The manufacturers of the film have, in most cases, suggested proper densities for their film, but there are far too many cases where these recommendations are not followed. This is something that can be made a recommended practice, but each producer will have to work out his own standards. Control of exposure for sound-tracks must be critically and carefully checked.

There must be something extremely fascinating about the manufacture of 16-mm reels, because it seems as if every machine shop in the country has put some sort of 16-mm reel on the market. After examining some of these reels, we wonder whether some of the manufacturers ever saw a 16-mm reel before. A few years ago we thought the 16-mm reel was pretty well standardized and would probably be rather hard to change. However, so many changes have been made during the past year or two that it is quite appropriate to suggest standardization. The original 16-mm reel was made for amateur use, and the idea of using a round hole on one side and a square hole on the other side was to make sure the reel was placed properly on the spindle. We have never yet seen a 16-mm professional who likes reels of this type. Editors and cutters of 16-mm film find them especially bad. We have found them with all sorts of hub sizes, some of which have been made so small that they will not work properly on certain types of take-ups at the beginning of the film.

We suggest that 16-mm reels be standardized with square holes on both sides, and that a certain hub diameter be chosen and adopted as standard.

Sixteen-mm editing equipment for the most part is made to handle reels instead of cores, as is common in 35-mm practice. Nearly everyone who has done much work with 16-mm uses these reels in editing, and most 16-mm originals received in laboratories for printing come in on reels. Furthermore, it is much safer and easier to handle film on reels.

We suggest, therefore, that it be recommended practice to handle 16-mm film on 16-mm reels.

We find that 16-mm film sent in for printing comes in all sorts of lengths. Different laboratories are set up to handle different lengths—some 100 feet, others 400 feet, up to 2000-ft rolls. This is all right except there should be a stopping point somewhere, and some sort of standard set for it. It is obviously impossible to get raw stock to match the exact footage for every show, and this becomes somewhat of a headache when sound is to be printed.

For a suggested recommended practice we suggest that original picture and sound-track for 16-mm be edited into lengths of 390 feet so they may be printed on standard length rolls of 400 feet. Leaders may bring the length up to 398 feet.

It probably does not make much difference in the final results, but we feel that it might be a good idea to standardize the direction of editing 16-mm film. Some persons edit from right to left and others from left to right. This is partially a matter of taste and partially a matter of equipment and the introduction of 16-mm soundtracks to the editing procedure. Certain equipment seems to work better in one direction than in the other. Reels with square holes on one side and round holes on the other call for editing in one direction, and reels with square holes on both sides will allow the editor to work in either direction. The splicer that is probably most commonly used for 16-mm editing is the Junior Griswold with the $\frac{1}{16}$ -inch splice. When using this on original sound-film it is almost necessary to edit from left to right. We have done so for years and have found a number of others who follow this procedure. All the equipment manufacturers do not agree and we suggest that some practice be recommended in order that all editing equipment be in agreement.

Producers of 16-mm pictures should standardize their techniques of performing certain operations and then adhere to their standards. We have received commercial pictures for printing that contained splices made on three or four different kinds of splicers. Such little things can make a show look like the work of an amateur instead of the work of a professional.

There is a great deal of work to be done in standardizing 16-mm production methods. This paper has listed only a few of the problems. It is hoped that other 16-mm producers will submit their suggestions and that eventually some of the suggested recommended practices will become standards.

REFERENCES

¹ OFFENHAUSER, W. H.: "A Review of the Question of 16-Mm Emulsion Position," *J. Soc. Mot. Pict. Eng.*, **XXXIX** (Aug., 1942), p. 123.

² THOMPSON, L.: "Some Equipment Problems of the Direct 16-Mm Producer," *J. Soc. Mot. Pict. Eng.*, **XLI** (July, 1943), p. 101.

DISCUSSION

MR. OFFENHAUSER: Mr. Thompson's paper contains much food for thought and raises a number of important related questions. Let us consider his recommendation of the Griswold Jr. splicer with a $1/16$ -inch splice.

For more than two years all splices made in original films in our laboratory have been made with a hot-splice type Bell & Howell laboratory splicer, converted to make a 0.070-inch straight splice. The splicer is accurately adjusted to produce a 0.010-inch overlap on either side of the sprocket-hole. On the right side of the splicer, an extension guide has been added that is quite long relative to the width of the film. This guide, which is chromium plated, makes it impossible to "skew" the film on the right side of the splicer with respect to the film on the left side of the splicer; the alignment of a splice is almost as good as that of a continuous piece of film.

The scraper for the splicer is very important; it is accurately adjusted for depth of cut and is kept honed by regular day-to-day maintenance. Splices are checked under a microscope regularly every day to make certain that nothing was damaged in the previous day's operations.

To those who inspect splices under a microscope (and for commercial 16-mm film, all of us should do so), the use of a Griswold Jr. splicer seems really crude. While it is probably one of the best, if not the best, hand-type splicer on the market, its shortcomings are such that our laboratory discarded it over two years ago. These shortcomings are:

- (1) It does not produce a "hot" splice.
- (2) It can not be adjusted to provide equal overlap on either side of the sprocket-hole.
- (3) When adjusted, it does not retain its adjustment.
- (4) It is not readily readjusted. (Readjustment is required periodically for every splicer.)

The characteristics of a splicer alone, however, do not tell the whole story; the question of the skill with which the splicer is used is so often a controlling factor that the mere *possession* of the best splicer is no assurance of the best results.

I am definitely not in favor of the Griswold Jr. splicer. Nothing less than the modified Bell & Howell laboratory splicer is suitable for large-scale high-quality work; an operator can make 50 per cent more splices per day with far less effort and fatigue. Every splice made should be a good one—and, with proper care, will be.

Very little maintenance attention is needed for the Bell & Howell splicer provided that those who use it are fairly skillful; however, a careless or unskilled person can, in a matter of seconds, put the splicer out of commission for a half-hour or longer. Adequate training of a careful person requires but a few hours if that person has the necessary aptitude.

What has just been said about splicers may be applied to any class of machinery. To use any machine successfully requires ever-vigilant inspection to assure that the machine (and the operator) continues to fulfill its purpose. This inspection not only cures difficulties when and as they arise, but also has as *its most important function the anticipating of difficulties before they have grown to significant magnitude.*

In a broader sense, this identical line of reasoning has already been successfully applied to armament production. Before a contractor who is to manufacture matériel receives the "green light," he must prove his ability to produce the desired product with the required quality—and to prove also that he can consistently maintain that quality in mass production. It is common practice that one or more of the successful samples is referred to when checking the product being currently produced. It has been the unswerving adherence to this policy that has made possible the manufacture of superior war supplies by manufacturers of refrigerators, automobiles, elevators, and a host of other peacetime products.

It would seem that this principle which has been so successful in armament procurement should be equally successful in the procurement of prints of our training films. Our laboratory industry has a tremendous advantage over the automobile industry and the refrigerator industry in the solution of the problem; the product of the film laboratory is not sensibly different in wartime from what it is in peacetime. The advantage should be reflected in the superiority of the product manufactured.

War has demanded a steady lifting of the quality level of all armament matériel; it should likewise demand a steady lifting of the quality level of all 16-mm prints of training films manufactured. This improvement can be readily obtained if our Government contracts will stress the product to be produced; and specify that product in measurable physical terms. The possession of a good bank statement and credit references together with particular facilities and special kinds of machinery such as Cinex testers and the like has no effect whatever upon the quality of the desired products: prints of training films.

There is dire need for rigid inspection of prints of training films and for quality specifications that will be sure to reject all defective prints. The all-too-common philosophy of "it costs too much to reject defective prints" and "it is good enough, anyhow" aggravates an already serious situation. We can be thankful that this sort of delusion was not shared by those who supplied the guns and bullets to the men on Guadalcanal.

Ever-vigilant inspection can do as much to improve the quality of 16-mm prints as it does to improve the quality of our ordnance. Let's give it a chance by *specifying the product, and not the tools* that someone happens to use to make the product. Let us have rigid inspection under product specifications, and enjoy the benefits of improved quality and lower costs resulting therefrom.

MR. TUTTLE: There has been and still is considerable confusion on the part of many users of Kodachrome film on the subject of the type of film to use with different light sources available.

The daylight type of Kodachrome film is suitably color-balanced so that it matches the color temperature of sunlight and blue sky which normally prevails in outdoor photographic work. The average mixture of sunlight and blue sky has a color temperature of about 6100° Kelvin. Therefore, the daylight type of

Kodachrome film is suitably color-balanced to match it. The Type *A* or artificial-light Kodachrome film is suitably color-balanced to match the photoflood type of illumination which has a color temperature of approximately 3450° Kelvin when used on a 120-volt line.

Filters were made available for these two films principally to permit the use of short unexposed pieces of film, remaining in the camera, in different types of illumination than originally specified. Rather than discard the film when the illumination is changed, it may be exposed by using the proper filter. For this purpose the No. 80 filter, which is light blue in color, was made available for use on the camera lens when daylight-type Kodachrome film is to be used indoors with photoflood illumination. The No. 85 or orange-colored filter was made available for use with the Type *A* film in using the short lengths of film out-of-doors. It is not the intention of the manufacturers of Kodachrome film that either film should be used as an all-purpose film with filters in opposite types of lighting for which the film was manufactured.

For the most satisfactory results on Kodachrome film the daylight type of film should be used when pictures are made in the normal mixture of sunlight and blue sky; Type *A* Kodachrome film should be used with the photoflood type of lamp on a line of proper voltage.

There are many factors relating to the use of filters with various light-sources which enter into such a discussion, and the technical reasons for not using filters, unless necessary, are many and require a much lengthier technical discussion than is permissible here. However, it is sufficient to say that if daylight type of Kodachrome film is used in sunlight and the Type *A* Kodachrome film is used with either the No. 1 or No. 2 photoflood lamps; and if a color-temperature meter is used to check the color quality of the light-source to make certain that it is approximately 3450° Kelvin, the best possible color rendition will be obtained on each type of film.

RESISTANCE OF GLASS TO THERMAL SHOCK*

CHARLES D. OUGHTON**

Summary.—The resistance of glass to thermal shock may be increased considerably by tempering which is the controlled introduction of strain. Tempering and annealing represent opposite extremes in heat treatment. Annealing removes strain by slow cooling while tempering introduces strain by rapid cooling. Glass fractures originate in regions of tension. When hot glass is subjected to a cold medium, a thermal gradient is introduced and the resulting strain distribution places the surface in a state of tension. If the tension exceeds the tensile strength of the glass a fracture will occur. Condenser lenses of projection machines are often subjected to thermal shock of this type. Tempering the glass places the surfaces under compression. A much greater thermal shock may then be applied without causing fracture, because sufficient stress must be introduced to completely neutralize the compression before the surface can go into tension and fail.

The breakage of reflectors, condensers, and occasionally projection lenses from heat is a common occurrence in lanterns with high intensity arcs. This is in accord with a number of everyday experiences, such as hot glass cracking when placed in cold water or touched to a cold object. Such breakage is a result of the tremendous shock to which glass may be subjected by even a small change in temperature. When costly optical glass is involved the phenomenon requires investigation from the practical viewpoint of how to make glass resistant to thermal shock.

Several general observations concerning glass should be noted. Glass expands when heated. The fractional amount by which it expands per degree of temperature rise is known as its coefficient of expansion. The coefficient varies with the composition of the glass; for example, glass having a relatively low percentage of silica has a high coefficient of expansion, while glass with a high silica content has a low coefficient of expansion. If one section of a plate of glass is raised to a relatively higher temperature than that of the surrounding or adjacent glass, the heated portion expands. The

* Presented at the 1943 Spring Meeting at New York.

** Scientific Bureau, Bausch & Lomb Optical Co., Rochester, N. Y.

thermal gradient from the heated section to the surrounding glass with a corresponding change in dimensions introduces stress. When stress exceeds the tensile strength of the glass a fracture occurs. Glass having a low coefficient of expansion will permit a greater temperature gradient for a given amount of stress than will glass with a high coefficient of expansion.

Stress caused by the thermal gradient produces strain in the glass. Two conditions of strain exist that are of interest in this instance—tension and compression. Bending a bar of glass places tensional strain on the side being stretched and compressional strain on the side being squeezed. A neutral layer of no strain will pass through the central region of the bar. Glass fractures originate in a region of tension. Considerable tension may be easily introduced where a flaw or weakness is present in the glass. Flaws are often microscopic and unnoticeable. It is reasonable to assume that surface flaws should weaken glass more than internal flaws and, correspondingly, more fractures originate at the surface.

With these considerations in mind, two solutions are available for increasing the resistance of glass to thermal shock: first, the glass may be given a high silica content with a correspondingly low coefficient of expansion; and, secondly, the glass may be tempered to place the outer region or surface layers under compressional strain, thus preventing tension from reaching the surface flaws. This latter approach presents rather interesting results.

Tempering involves a heat treatment that is the opposite extreme to annealing. Annealing consists of slow cooling to remove strain. Tempering introduces strain by rapid cooling. In both instances the glass is heated to a temperature slightly below the softening temperature. In this temperature range the stress is completely removed from the glass. By cooling slowly to room temperature, over a period of hours, the glass assumes an unstrained or annealed condition. By cooling the glass to room temperature in an interval of a few minutes, in a stream of air or by immersion in a liquid bath, the glass is placed in a strained condition and is said to be tempered.

If tempered properly such glass is capable of resisting considerably more thermal and physical shock than annealed glass. It is placed on the market under a variety of trade names and is used in laboratory glassware, safety goggles, car windows, *etc.*, where physical and thermal shocks are likely to occur.

An examination of the strain conditions in tempered glass will

indicate, in general, how the glass is made resistant to thermal shock. To explain in detail the origin and conditions of strain in tempered glass is beyond the scope of this paper. It will be sufficient to state that in tempered glass the entire surface region is in a state of compressional strain; the center is under tension, and between the center and the surface there is a neutral zone of isotropic strain. When hot glass is suddenly cooled the outer region solidifies over an expanded hot central region. As the central region is cooled to room temperature by the cold surface, it can not contract to its normal dimensions because of the solidified but expanded outer surface of the glass. This leaves the center under tension.

Remembering that in untempered glass fractures originate at surface flaws when the tension around the flaw exceeds the tensile strength of the glass, it is apparent that the state of strain introduced into the glass by tempering should increase its resistance to thermal shock. Before the tensional stress at the surface can exceed the tensile strength of the glass after tempering, it must counteract the compressional stress that has been introduced over the complete surface. Thus, a more severe shock is required to fracture tempered glass than untempered glass. When tempered glass does fracture indications show that the break often originates in the central tensional region.

Glass is most likely to break when it is plunged suddenly from a hot medium into a cold medium. In heating untempered glass from room temperature to a much higher temperature (cold to hot thermal shock), the surface is placed in a state of temporary compressional strain. Thus there is little chance of a break originating under this condition. But, when glass is cooled rapidly from a high temperature to a low temperature, the surface is placed in a state of temporary tensional strain and a fracture is likely to occur. Condenser lenses of projection machines are almost constantly subjected to thermal shock of this latter type. Their fracture is a familiar and frequent occurrence, and therefore the lenses serve as excellent examples for the application of the above principles.

Properly annealed condenser lenses of the highest illuminating efficiency, even when made of the best thermal shock-resistant glass, have a very brief life when used with high-intensity arcs. This is due to the tremendous thermal shock to which the lenses are subjected. Only a few inches from the plano side of the condenser is a carbon arc carrying, perhaps, 175 amperes which acts as a source of

heat. While this side of the lens is held at a high temperature, the opposite side radiates the heat and has a considerably lower temperature. The result is a thermal gradient that may cause fracture. Ordinary optical crown glass would last only a few minutes under these conditions. Even well-annealed Pyrex glass with a much lower coefficient of expansion fails to withstand such thermal shock for a reasonable length of time. A solution to the problem is found in fused silica, often referred to as fused quartz, with $\frac{1}{7}$ th the coefficient of expansion of Pyrex. Fused silica is expensive to prepare, but serves satisfactorily until the surface becomes pitted from the arc.

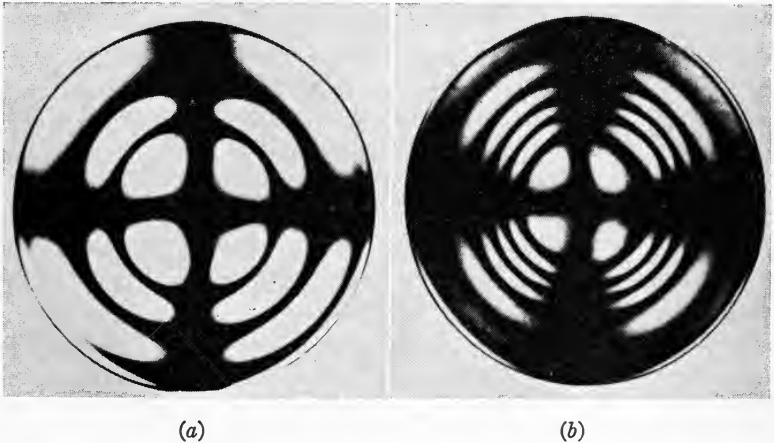


FIG. 1. Polariscope strain patterns in condenser lenses (a) before and (b) after use with source of heat on plano side. The increased number of bands in (b) indicates that the compressional strain on the plano side has been partially removed.

A lens made of glass having a low coefficient of expansion, such as Pyrex, will also last until the surface becomes pitted if it is tempered properly. However, the life of a tempered lens is limited by the temperature to which the surface near the arc is heated. When used with a high-intensity arc the tempered lenses will eventually break. A comparison of the strain pattern in a condenser lens after tempering and again after 50 hours' use in a motion picture projector, using a 175-ampere arc, reveals a rather startling phenomenon: the lens appears to have more strain after use than before. Fig. 1 illustrates this difference: (a) is a photograph of the strain

pattern of a tempered condenser lens in plane polarized light before being subjected to the treatment described above; (b) shows the lens after use. The additional dark bands indicate the change in the

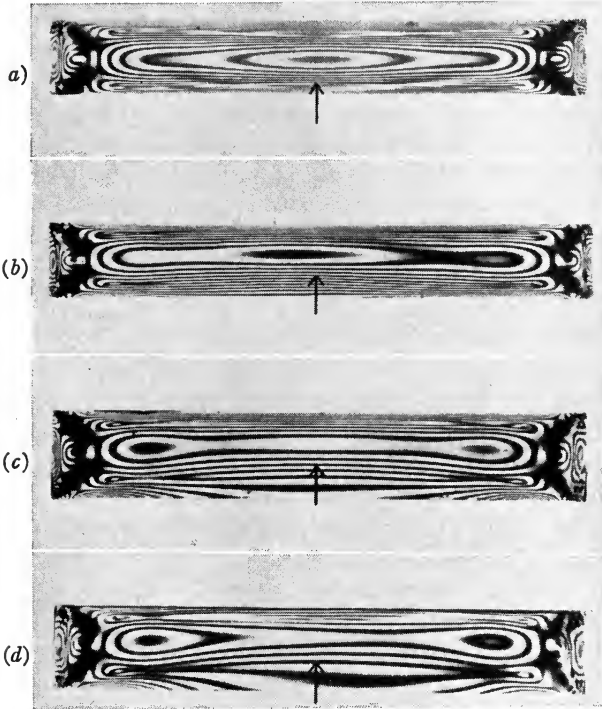


FIG. 2. (a) Polariscope strain pattern in a glass strip tempered symmetrically from top and bottom with air.

(b), (c), and (d). The same strip after successively increasing periods of heat application to the lower surface. The arrows indicate the neutral band of zero resultant stress. The outside of the glass is under resultant compressional strain and the inside under resultant tensional strain. The decrease in the number of neutral bands between the neutral layer and the lower surface shows that the heat treatment has progressively relieved the compressional stresses in this region.

amount of resultant strain. From the analysis of the method of introducing strain into glass it may be concluded that no strain has been added, because the glass temperature did not reach the annealing

range and it received a gradual chilling in cooling to normal, whereas it originally received a severe chilling.

The solution to this problem is found in the manner by which the lens is heated in the projector. The plano side of the condenser lens is usually placed only a few inches from the carbon arc source. Carbon arcs drawing a high current act as a source of considerable heat that raises the temperature of the plano side of the condenser thus decreasing the viscosity of the glass and permitting the gradual release of the surface layers of strain. This is shown in Fig. 2. A strip of glass 4 in. long, $\frac{3}{4}$ in. wide and $\frac{1}{2}$ in. thick was air tempered. Fig. 2 (a) shows the strain pattern in the strip as a result of cooling uniformly on the upper and lower sides. Considerable heat was then applied to the lower side of strip (a). Fig. 2 (b), (c), and (d) show the gradual release of strain as the heat was applied for successively increasing lengths of time. The arrow marks the neutral line of zero resultant stress. The decrease in the number of dark bands between the neutral line and the surface gives a measure of the decrease in the compressional strain on the surface of the glass. Considerably more strain was released on the side heated owing to the lower viscosity of the glass in that region. Because the temperature in a condenser lens varies from a high value on the plano side to a low value on the convex side, more strain should be released on the plano side. The center and convex side of the lens tend to remain in tensional and compressional states of strain as limited by the viscosity of the glass which will vary according to the heat distribution. The strain pattern in the lens following exposure to a high temperature for some time gives indications of considerably more strain. Previously, the strain viewed in the polariscope was made up of compression on the convex side, minus tension in the central region, plus compression on the plano surface which, in the usual methods of tempering thick lenses, will add up to resultant tension. This tension is indicated in the polariscope by a series of colored bands. After use the strain pattern is made up of compression on the convex side, minus tension in the central region, plus less compression than previously on the plano side. This gives a greater resultant tension which is indicated in the lens by an increase in the number of colored bands (Fig. 1). Actually, there is less strain in the lens, and also a less effective distribution of the remaining strain.

Over a period of time the compressional strain on the plano side

will be released sufficiently to permit the surface flaws to enter a state of tension and cause a fracture. To counteract this release of strain special tempering techniques have been and are being developed to place a thicker layer of compression on the glass surface.

Although tempered glass will not endure indefinitely under severe thermal shock, tempering must be considered as a useful method of increasing the resistance of glass to thermal shock. One of the best examples of its usefulness is found in condenser lenses. Whereas annealed condensers under severe thermal shock in motion picture projectors will last only a few hours, the tempered condensers will last until the surface becomes pitted.

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 or microfilm copies of articles in magazines that are available may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y., at prevailing rates.

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A MOTION PICTURE ARC-LIGHTING GENERATOR FILTER

B. F. MILLER*

Summary.—The general means heretofore employed to reduce the commutator noises emitted by arc lamps operated from direct current generator sets is outlined, and the deficiencies of such equipment are noted. The design of an electrical filter unit, which is extremely compact as compared to previously employed equipment and which is capable of handling the full load output of studio stage-lighting generators, is described. This filter completely suppresses all arc-lamp noises resulting from generator commutator ripple, may be permanently associated with any studio generator set, eliminates the need for repeated installations of large numbers of choke coils on the set, and requires no servicing. The unit is capable of withstanding current overloads in excess of 100 per cent indefinitely.

The "whistle" present in arc lamps owing to the commutator ripple of the power supply generators has caused recording engineers endless difficulty since the advent of sound motion pictures. Many attempts have been made to minimize or to eliminate this noise, but so far as is known, none of the remedies heretofore proposed has been entirely successful. Almost all the studio generator equipment is shunted by large electrolytic condensers, and in a few instances several turns of heavy copper cable have been employed as an air-core inductance in series with the load circuit. Such air-core inductances are not entirely satisfactory, however, since the attainment of sufficiently high values of inductance is usually accompanied by the introduction of excessive amounts of resistance in the load circuit.

In addition to the overall filtering described above, it has been customary to employ large air-core chokes, each having a current-carrying capacity of approximately 1000 amperes, on each set utilizing arc lamps. Some five feet in diameter and weighing approximately a half-ton, each of these chokes is capable of providing a certain amount of filtering to a load consisting of eight to twelve arc lamps. These chokes are commonly mounted on dollies so that they may be transported from set to set.

* Warner Bros. Pictures, Inc., Burbank, Calif.

Since the combined filtering provided by the individual chokes on the set and that of the generator filters is usually insufficient to prevent audible noise from the arc lamps, additional filtering is generally provided for each lamp in the form of small iron-core choke coils or "whistle-boxes," each weighing approximately 50 lbs.

Under extremely favorable circumstances this filtering combination is sufficient to eliminate the bulk of the objectionable singing noise characteristic of arc-lamp operation. Under more adverse conditions, however, recordings are still marred by arc-lamp background noise. A further reduction in lamp noise may be made through first-class maintenance of generator equipment, since commutator ripple magnitude is partially determined by the condition of generator commutators and brushes. However, a definite lower limit of ripple voltage exists for each generator unit; when this limit has been attained the remaining necessary reduction in ripple voltage must be achieved through the use of electrical filtering devices. Technicolor productions are particularly susceptible to lamp-noise trouble, since arc-lighting is used almost exclusively for color photography.

In addition to the fact that complete suppression of lamp noise is extremely difficult with the type of filtering described, the transportation and rigging of the large number of choke coils necessary for each operating set is time-consuming and costly. A more desirable form of filtering would therefore provide the following features:

(1) Complete suppression of all commutator ripple noise from arc lamps, with an adequate margin of safety for highly variable lamp loads and for variations in magnitude of generator-ripple voltage.

(2) A single filter unit which could be permanently associated with a lighting-generator set.

(3) A unit whose general design would prove adequate for a variety of generator types.

(4) A unit which would provide adequate filtering even though the generator unit with which it was associated might frequently be subjected to moderate overloading.

(5) An essentially compact unit, so that it might be conveniently installed adjacent to its associated generator.

The desirability of designing a unit possessing these features was recently called to the attention of the writer by Mr. Lee Adams of Warner Bros. Electrical Department. The remainder of this paper is devoted to an outline of the unit designed and a brief summary of

the conclusions reached since the units have been employed in production.

A number of noise-level studies were first made on typical arc lamps with the aid of a General Radio sound-level meter. During the studies it was determined that arc-lamp noise would be reduced to a negligible value if the generator ripple was reduced by a factor of approximately 30 decibels. Oscillographic studies were next conducted to determine the magnitude and frequency distribution of the principal ripple-voltage components present in the generator terminal voltage. The data so obtained indicated a predominant low-frequency component of approximately 900 cycles per second, having an amplitude of about three volts, as well as numerous higher frequency components of equal or lesser magnitudes. Tests on several similar generators indicated that the data obtained from the first unit tested might be taken as typical.

The full-load current rating of the generators involved was 1200 amperes, and the terminal voltage of the machines was 120 volts. The minimum normal load impedance, neglecting any inductance present in stage feeder circuits, was therefore equal to 0.10 ohm. After some consideration it was decided to design a simple "constant k "* prototype section generator filter which would have a characteristic impedance of 0.05 ohm and would provide a minimum of 40 decibels attenuation to the lowest frequency ripple component present in the generator terminal voltage. This choice was based upon the following grounds:

(1) Since the filter would be terminated in a highly variable load impedance, the variation in filtering attained would be minimized if the filter characteristic impedance were made lower than the lowest value of generator load impedance.

(2) Because of the large number of high-frequency commutator ripple components present at the generator terminals, it was necessary to insure that adequate filtering would be provided over a very wide frequency band; this could most readily be accomplished through the use of prototype filter sections.

* *Ed. Note:* A "constant k " type filter is one for which the relation $Z_1 Z_2 = k^2$ holds, where Z_1 = the impedance of the series arm and Z_2 = the impedance of the shunt arm. An " M -derived" type filter is one in which the image impedances are equal to those of a "constant k " type but whose configuration, attenuation, and phase characteristics are, in general, different from those of the constant k type. (See "Transmission Networks and Wave Filters," T. E. Shea, D. Van Nostrand Co., 1929, Chap. VII.)

(3) The incorporation of *M*-derived filter sections would have necessitated the use of a larger number of filter elements and would make the effectiveness of the filter somewhat variable with different types of generator equipment.

A preliminary study of the filter requirements led to the conclusion that the most economical design would consist of one and one-half prototype low-pass sections, having a cut-off frequency of approximately 400 cycles per second. Upon setting the filter characteristic impedance equal to Z_0 and the filter cut-off frequency equal to f_c , the

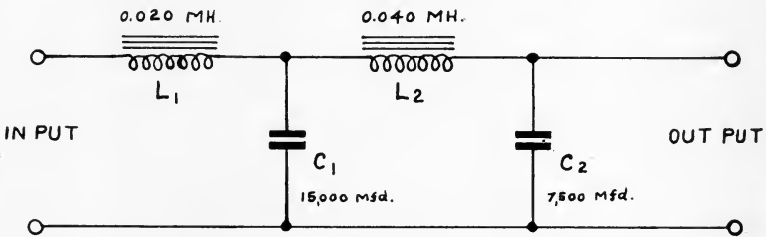


FIG. 1.

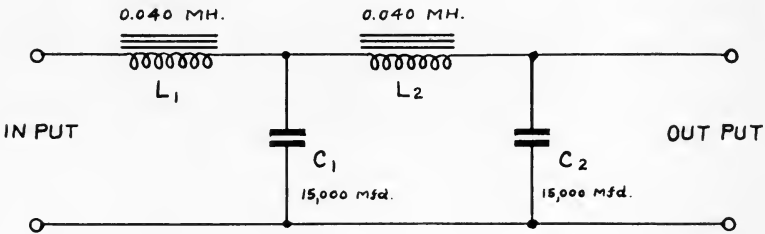


FIG. 2.

required inductance L and capacitance C for the prototype section were determined from the well known relationships:

$$L = \frac{Z_0}{\pi f_c}; \quad C = \frac{1}{\pi f_c Z_0}.$$

Upon setting $Z_0 = 0.05$ and $f_c = 400$, the required value of L becomes equal to 40 microhenries and that of C equal to 15,900 microfarads. The latter value was actually reduced to 15,000 microfarads, since it could then be constructed readily by employing six 2500-microfarad capacitor banks.

Employing the L and C values just derived the filter took the form shown in Fig. 1. Calculations of the core size required for the filter

inductances were next carried out with the aid of formulas previously derived from extended studies on transformer and reactor designs. From these it was determined that a core consisting of approximately 113.5 lbs of transformer *A* grade silicon steel would suffice if a normal maximum core flux density of 10 kilogausses was employed. Allowing a normal maximum of 400 amperes per square inch of winding cross-sectional area, the coil copper requirements were calculated as 53.5 lbs.



FIG. 3. The new-type filtering equipment used on a set requiring 5000 amperes.

The volume of iron and copper required for the 40-microhenry inductance was considered sufficiently small to make it desirable to employ identical inductances in both filter sections. An additional margin in the amount of filtering provided could also be obtained at moderately low cost by employing identical capacitor banks at both points in the filter. Accordingly, the initial design was modified to that shown in Fig. 2. This unit is capable of producing an average of approximately 50 decibels attenuation to ripple frequencies of about 900 cycles per second or, roughly, 20 decibels more than the amount actually required. Higher ripple frequencies are attenuated

in a somewhat greater degree. Sufficient copper and iron are provided in the filter inductances so that overloads of fifty per cent may be tolerated with only a minor reduction in the degree of filtering attained.

The filter inductances as finally constructed consist of a single-turn solid-cast copper winding having a length of 57 inches, a cross-section of 3 square inches, a weight of 55 lbs, and a resistance of 0.00002 ohm. The core consists of a 20-inch stack of high-silicon steel laminations weighing 120 lbs and is provided with a $\frac{1}{16}$ -inch air gap to satisfy inductance requirements. When the coil is carrying 1200

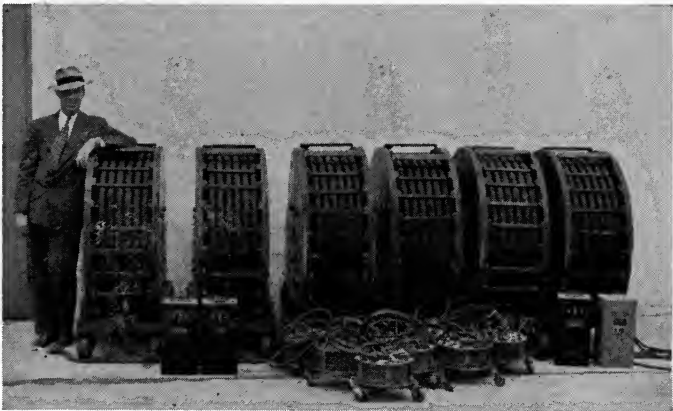


FIG. 4. The old-type filtering equipment used on a set requiring 5000 amperes.

amperes d-c, the inductance is 40 microhenries, and is considerably higher than this value at lower values of load currents. The full-load voltage drop across the inductance is approximately 25 millivolts which is negligible. Normal full-load power dissipation in the coil winding is but 30 watts.

The experimental filter constructed in accordance with the above design proved so satisfactory on tests that a sufficient number of additional units have been constructed to equip every fixed and portable generator in the studio. Since these installations were completed not a single case of trouble from arc-lamp whistle has been reported, and the filter has proved satisfactory even when carrying an overload of 1500 amperes. Figs. 3 and 4 compare the new and old filtering equipment on a set requiring 5000 amperes.

The advantages and economies resulting from these installations may be summarized as follows:

(1) The filters eliminate all commutator ripple noise from arc lamps.

(2) All combination and individual arc-lamp chokes are eliminated, resulting in a saving of time on the sets, a saving in labor formerly required for transporting and installing the chokes, and in maintenance costs on individual chokes.

(3) The filters are effective at all values of load current, introduce no appreciable voltage drop in the load circuit, and require no maintenance of any kind.

(4) There is a great saving in cost and in the use of critical materials owing, in no small measure, to the fact that the new filter inductances require only one-fourteenth as much copper as formerly required for a single large-size stage choke coil.

ERRATUM

In the October, 1943, issue of the JOURNAL, Equation (3) on p. 286 of the paper by Ellsworth D. Cook entitled "The General Electric Television Film Projector," should read as follows:

$$(a) = \frac{S}{\sqrt{2}}$$

NOTES ON THE APPLICATION OF FINE-GRAIN FILM TO 16-MM MOTION PICTURES*

WM. H. OFFENHAUSER, JR.**

Summary.—In September, 1939, J. A. Maurer reported in the JOURNAL on "The Present Technical Status of 16-Mm Sound-Film" and in November, 1940, on "Commercial Motion Picture Production with 16-Mm Equipment." The first paper compared the quality of direct 16-mm sound with that of reduction prints from 35-mm negatives; the second compared the graininess of prints by the reversal (intermediate fine-grain duplicate negative) fine-grain print method with reduction prints from 35-mm original negatives. The comparison appeared so favorable to direct 16-mm that the next step was obvious: to put the procedures into commercial use.

Early experience with Dupont fine-grain materials in 1930 and 1931 left behind an elementary yet important consideration: if the expected improvements from the use of fine-grain materials and methods were to materialize, something more than the mere use of fine-grain materials was required. Muck in developer, fixer, and wash water must be reduced; films must be properly dried. Only with these elementary conditions satisfied could the quality be significantly improved.

Dupont was the first manufacturer to offer fine-grain release print film to the 16-mm market; the experience with Dupont 605 was so satisfactory commercially that all ordinary positive materials were dropped entirely. Eastman 5203 was found to be the best duplicate negative material available; all other materials were dropped. For original negatives in 16-mm direct sound recording, Agfa 250, a high-resolving-power yellow-dye film, was the first satisfactory material on the market and remained without competitors for several years. With such excellent materials under accurate control, decidedly improved films were bound to result.

It is interesting to note that these present-day materials have a resolving power of the order of 100 lines per mm; this is of the same general order as that of the materials that Dupont produced experimentally in 1931. While resolving power of this order is considered sufficient for better-grade present-day projectors, there is real need for pushing the quality standard still farther upward to 150 lines per mm. The techniques for the manufacture of such materials are fairly well known today; the big need is for Government contracts to call for such high-grade materials and for Government inspectors rigidly to reject inferior materials such as ordinary positive prints.

The selection of the most suitable materials and the manner of determining the operating conditions for the machinery selected are described.

Introduction.—When a new 16-mm print is removed from its shipping container for the first time and placed on a projector for its first run before a professional audience, there is a momentary silence; the

* Presented at the 1943 Spring Meeting at New York.

** Precision Film Laboratories, New York.

audience evaluates quickly the quality of the projected picture and sound. As matters stand today, a user has no way of knowing beforehand just what the quality of his print is going to be; there is no quality standard for 16-mm prints.

It is no longer true that the output of 16-mm prints is so small and the distribution so restricted that a quality standard of some sort would not be welcome. With millions of feet of film pouring out of laboratories each week at Government expense and with user groups varying in size from three or four to as many as 1000, some sort of quality measure would seem sorely needed.

Standardization of 16-Mm Equipment.—For some time we have had available recommendations concerning the 16-mm sound projector; these were prepared by the Non-Theatrical Equipment Committee of the Society at the request of the Committee on Scientific Aids to Learning, of the National Research Council. Armed with a few facts about the room in which films are to be projected, it is not a difficult matter to select the proper size and type of screen and to determine the lumens output required of the projector. These data are found in the Report of the Non-Theatrical Equipment Committee published in the July, 1941, issue of the JOURNAL.

All reputable manufacturers can provide certified data concerning each type of machine manufactured; all machines of a particular type are guaranteed to perform as well as the sample machine whose performance has been certified. With the ready availability of such information and performance guarantees, there is little reason today why a new machine (when so guaranteed) should not be well suited to its intended use.

Quality Status of 16-Mm Prints.—If the quality status of 16-mm prints for such machines is investigated, there appears to be no distinction between a print suitable for an audience of three or four and a print suitable for 1000—unless we accept the term “fine-grain.” The distinction is quite vague; we use the term “fine-grain” for the higher-grade film, but there is no name at all—or only the name “ordinary print”—for the other. There is no precise explanation of what “fine-grain” means or how “fine” a fine-grain film must be to be suitable for an audience of 1000.

Quality Status of 35-Mm.—As a starting point, consider the quality of the projected picture and sound in an up-to-date and well-maintained 35-mm entertainment theater of 1000 seats. Such a quality reference is reasonable; it is a convenient reference in which the pic-

ture is of good quality and the sound is of good quality. The standard is commercially feasible yet sufficiently high to make the projected result clearly understandable to the audience; there are no distractions of poor quality or of extraneous noise to interfere with the subject matter presented. The projection equipment of the reference theater has been standardized both for picture projection and for sound projection. Equipment is as carefully designed to project sound into all parts of the audience area as to project the picture properly into that area.

Sixteen-mm non-theatrical equipment has not yet been standardized to such a high degree; the trend seems to indicate that in this respect 16-mm will follow in the footsteps of its larger counterpart and benefit by its progress.

Resolving Power Requirements.—The raw film used for release prints in the reference 35-mm theater is ordinary nitrate positive; such film has a resolving power of approximately 55 lines per mm. (Eastman 1301 and Dupont 200 are typical ordinary positive materials.) To obtain equivalent screen definition from a 16-mm material would require greater resolution of that material in the ratio of the image areas; or, more conveniently, in the inverse ratio of the film speeds; 90/36 or $2\frac{1}{2}$. Fifty-five lines per mm multiplied by $2\frac{1}{2}$ equals $137\frac{1}{2}$ lines per mm; this is the minimum resolving power required. It is apparent that ordinary positive 16-mm materials such as Eastman 5301, Dupont 600, and Agfa 220 are woefully inadequate; materials of far higher resolving power are required for prints that are comparable to 35-mm in quality.

The Resolving Power of Available Materials.—Eastman Kodak has recently published a welcome book, "Properties and Performance of Eastman 35-Mm and 16-Mm Films for Professional Use." This book makes it convenient to choose among the various Eastman materials available. If we rigidly adhere to our criterion of $137\frac{1}{2}$ lines per mm and expect to obtain this result under the "average" developing conditions therein described, there is but one Eastman material available, EK 5365, which has sufficient resolving power; the value is 150 lines per mm. Under the processing conditions specified, this film is to be developed for $9\frac{1}{2}$ minutes in an SD-21 developer with a IIb gamma of 1.40.* Table I shows the available materials, their suitability, and resolving power.

* SD-21 is the equivalent of a seasoned or partially exhausted D-76 metol-hydroquinone negative developer.

TABLE I
Available Materials, Their Suitability, and Resolving Power

Material	Rated Resolving Power (lines/mm)	Eastman	Dupont	Agfa
Ordinary Positive	55 (<i>Not Recommended</i>)	No. 5301 (<i>Not Recommended</i>)	No. 600 (<i>Not Recommended</i>)	No. 220 (<i>Not Recommended</i>)
Fine-grain Positive	90	No. 5302 (<i>Satisfactory Alternate</i>)	No. 605 (<i>Preferred</i>)	
Fine-grain Dupe Negative	110	No. 5203 (<i>Preferred</i>)		
Fine-grain Master Positive (Yellow-dyed)	150	No. 5365* (<i>Preferred</i>)		
Sound-recording Negative		No. 5357 (<i>Not Recommended</i>) No. 5372 (<i>Satisfactory Alternate</i>)	No. 602 (<i>Not Recommended</i>)	No. 250 (<i>Preferred</i>)
Original Picture	75	Kodachrome (<i>Preferred</i>)		

Cost Factors.—For commercial laboratory use at the present time, the selection of a material for release printing that would require a $9\frac{1}{2}$ -minute developing time is impracticable; with existing equipment, the average laboratory can not afford a developing time greater than approximately 4 minutes. If we add the additional cost of the raw film (the price of 5365 is higher than that of ordinary positive) to the additional processing cost (assuming the developing time of ordinary positive to be 2 to 3 minutes) the resulting price would represent such a large percentage increase that some very extensive and highly expensive persuasion would be required to convince a customer (such as the Government) of the increase in utility that would justify such an increase in price.

Choice of Positive Materials.—With these very fundamental limitations, it is apparent that the choice of a suitable release print ma-

* Recommended for release prints because of fineness of grain (when developed in a negative bath that is low in bromide).

terial is narrowed down to a fine-grain positive type of material that can be developed with fine-grain and high-resolving-power characteristics in a relatively high-energy developer at a short developing time. Automatically the choice rests between two materials, Eastman 5302 and Dupont 605. In either case, since a short developing time is required, a developer high in metol, elon, or rhodol (different trade names for the same developing agent) is required. The practical choice between the two film materials will be dealt with later in this paper.

Economics of Duplicate Negatives.—When the subject of duplicate negatives and master positives is considered, the economics of the problem changes. In a sense, duplicate negatives and master positives are to a film laboratory what special production tools such as automatic lathes, milling machines, drop forge presses, special jigs and dies, *etc.*, are to a factory. The automobile industry long ago pointed out the business wisdom of buying very expensive tools for mass production; where mass production of prints is the objective, it would seem to be business wisdom to make the best duplicate negatives and master positives that we know how. If we have a genuine interest in quality, the problem is to determine what *is* the best duplicate negative or master positive with little regard for cost—and to go ahead and make it.

The General Method.—If the original is a direct 16-mm reversal or Kodachrome, the best black-and-white release prints (all things considered) that can be made in quantity are made by the duplicate negative-release positive print method. The emulsion position of the release print is standard; almost all sound projectors manufactured are adjusted to proper focus of sound optics for this emulsion position. Sound is of best quality by this method; we can take advantage of the distortion cancellation technique that is practically universal for variable-area film. And last but not least, the contrast of the picture can be nicely controlled to produce whatever contrast is desired in the finished print. With such a complement of advantages, the method may be considered almost ideal.

Some History of Fine-Grain Film.—Before going into the procedure and how it is worked out, it seems appropriate to record here some of the unpublished history of fine-grain film that has a direct bearing upon the materials and methods now employed. In 1930 when John A. Maurer was working on a sound-on-film arrangement called "The Talking Book," the resolving power of available sound-recording

films and of release print materials was poor as measured by present-day standards. In a variable-area negative, it was quite a feat to record 5000 cps on 35-mm film with a track density (unmodulated) of 1.5 and a fog density as low as 0.08; many of us would have felt overjoyed if we could keep the fog density consistently below 0.06 for a track of 1.6 unmodulated density. We had no special films; release positive was used for sound negatives as well as for release prints. Fog due to development was great and the optical systems commercially used produced a superabundance of stray light.

It was at this stage of the art that Mr. Oakley of Dupont was asked to work out some fine-grain materials for the talking-book project. The requirements laid down were as unique as they were simple:

"Use every precaution to keep the grain fine—a Lippman type emulsion is the sort of thing we need." With this all-inclusive requirement as a guide, Drs. V. B. Sease, D. R. White, and others of the Dupont research group quietly went to work.

The details of the work are too long to report here; for a period of a year or more Mr. Maurer made recordings every week, including a number of recordings of Walter Damrosch's Musical Appreciation Hour. Often during the year the author listened to impromptu recorded concerts when we would compare the quality of the older talking-book recordings with that of the newer ones.

The quality was somewhat better than the best disk records of that time; it was marred far more by the microphonic ping of the 224 tube in one of the low-level amplifier stages than by any "ground noise" or distortion evident in the speech of Dr. Damrosch, in the music of his illustrative piano, or in the orchestral performance that followed. The recordings as reproduced were especially free of noise and distortion.

What is especially significant is that these recordings utilized film running at 45 feet per minute with a maximum sound-track width of only 2 mils as compared with 60 mils for standard 16-mm tracks. There were more than 300 sound-tracks on a print of one of these films that the writer gave to Col. M. E. Gillette in 1934 for his sample collection.

Experience with the talking book sharply accentuated the importance of fine-grain film and its processing. In a special series of fine-grain tests in which distilled water was used instead of water filtered and cleaned in the manner typical of commercial laboratories at the time, noise was reduced some 10 db. Even today a reduction

of 10 db in noise is something to be sought for; if water cleanliness will do it, every effort should be made to keep the water clean. (Dirty water is still a serious problem in commercial processing.)

The quality of the talking-book records was remarkable for the time; most commercial laboratories processing 16-mm release prints today would be more than pleased with equal quality. Contemporary production prints do not yet equal those old records in quality; the reason for the technical superiority of the old records is quite simple; the resolving power of the special 1931 film was 100 to 110 lines per millimeter, about double that of the ordinary positive used by most laboratories today.

Fine-Grain Release-Print Material: Dupont 610.—With such a background as this, it was only logical for Precision Film Laboratories to grasp the earliest opportunity to use fine-grain materials in 16-mm. When Dupont began to market their 610 emulsion several years ago, it was considered most desirable to adapt the methods to be used to the available material; it was felt that commercial benefit could be derived from the excellent basic work accomplished in 1930 and 1931. Comparison was possible only between Dupont fine-grain 610 and ordinary positive materials (there were no other fine-grain materials on the market). Within a year after the first trials of this material, our Laboratory dropped ordinary positive altogether and has processed none since.

Dupont 605.—For well over a year after the first tests with Dupont 610, no film manufacturer other than Dupont offered a 16-mm fine-grain release print material. During this interval the film was being constantly improved, and later Dupont 605 was evolved. This new material proved even better than its predecessor and, since its advantages were outstanding, our Laboratory standardized on it as the one and only raw film for release print purposes.

Today's Status—Conditions of Use.—For procedure simplification and for best quality and maximal uniformity of product, our Laboratory still uses one release positive material: Dupont 605. This material satisfies the commercial requirements with regard to operating costs, and, in addition, to such technical requirements as image tone, photographic scale, resolving power, and graininess, as well as a very desirable hardness of emulsion that makes "protective coatings" and similar treatment unnecessary for prints projected in machines that are kept in good repair.

To get the most out of this excellent fine-grain release print ma-

terial, all release prints are developed at *one* developing time. All printers are of the step-contact type; these seem to give best image definition. For uniformity, all printers are of the same type; all use the same type of lamp as a light-source, all run at the same speed, and all will print any dupe negative (made in our Laboratory) on the *same single* printer light. Within the past two years we have found no outstanding attributes of any other fine-grain release positive materials to justify altering this procedure.

In practice, only the compensations for the batch-to-batch variations of sensitometric characteristics are necessary to keep the process well under control. To develop this fine-grain film properly necessitated an increase in developer concentration of about one-third together with an increase in rhodol (the increase is more than two to one) and a reduction in the bromide of about one-third. The reference formula is the Eastman *D-16*.

With the experience of 1931 in regard to the talking-book project in mind, special pains are taken to filter and clean all water, to maintain temperature control, and last but not least, to control the cleanliness, the humidity, and the temperature of the drybox air. It would seem futile to go through all the motions of control that have been indicated, and then spoil the good work by imbedding muck from dirty chemical baths or wash water, and by forcibly blowing dust and other dirt particles right into the emulsion during the drying process. A 10-db reduction in noise which can be achieved by cleanliness is well worth striving to obtain. As has been explained in some detail in a previous paper,¹ great care and attention are given to proper fixing and drying. Film may be taken directly from the developing machine take-up for immediate projection on the Bell & Howell Utility projectors that are used for inspection. No "preservative" is needed to "ease" the film through the projector; the film is not "green."

The Duplicate Negative.—The positive print is held within quite narrow sensitometric limits; these limits are predetermined by the characteristics of the film itself, by the developing machine, and by the machinery used to expose the film. To produce a release print in the manner described requires an "evened-out" duplicate negative that is quite uniform; the characteristics of this duplicate negative are the key to the methods employed.

As in the case of the release positive material, the first step is to select the *one* most desirable duplicate negative raw film; the material with the highest resolving power and the most suitable scale

and gamma. In this case the choice was Eastman 5203. The rated resolving power is 110 lines per mm in an *SD-21* developer at a *IIb* control gamma of 0.65 (which represents a developing time of 6 minutes). To make fine-grain prints of proper contrast from reversal or Kodachrome originals with this material for the intermediate duplicate negative requires a smaller *IIb* control gamma (under our conditions) than is specified in the Eastman data. The first step was to determine what the control gamma should be for an "average" reversal or Kodachrome and to make adjustments in the developer bath and elsewhere so that our regular step-contact printers with their 20-light scales may be used in making these dupe negatives. As before, the machines were the same, the lamps were the same; obviously the juggling had to be done with the developer bath. We made one slight change; since there was plenty of exposure available, a filter was introduced to limit the exposing light to wavelengths shorter than 5000 Ångstroms. This helped to reduce the contrast and improve the definition and graininess of the dupe negative. (EK 5203 is panchromatic.)

Timing.—We had observed in printing a black-and-white duplicate negative from a Kodachrome original, that the timing was quite similar to that used in printing a Kodachrome duplicate from the same original. If the contrast of the finished products were supposed to be the same, there would seem to be little reason why it should not be possible to make the timing of them identical. This proved to be practicable as a commercial procedure; today the timing of a Kodachrome original for black-and-white prints is identical to its timing for Kodachrome duplicates. When this procedure was first tried commercially, slight readjustments in dupe negative developing were required. It may be interesting to know that the developer bath for duplicate negatives is used also for original negative; the only difference is an appreciably longer developing time for original negative. The amount of 16-mm negative in use is very small; negative is not used today in any project where a large number of prints is required.

Developing the Dupe Negative.—The bath for the dupe negative is such as to produce the desired gamma with a developing time of 3 to 4 minutes. The *IIb* control gamma for EK 5203 under our conditions is in the range 0.35 to 0.40, slightly lower than that of usual developers. Accurate sensitometric control is a "must"; experience over a long period points out quite forcibly that no timer can properly

time a film for printing unless the process is well "tied down." When we first tried to make prints from dupe negatives, it did not take long to recognize that timing a duplicate negative for a print usually resulted in a *poorer* print than a one-light print from the same dupe negative. Obviously the error was in making the dupe negative from the original; the proper correction of the error is correction at the source: a new dupe negative. The resulting technique—with all timing in making the dupe negative and one-light printing of the dupe for making the release prints—would seem to be almost ideal for making highest-quality fine-grain black-and-white prints in large quantity with greatest uniformity.

16-Mm Prints from 35-Mm Negatives.—When it is necessary to make good fine-grain 16-mm prints from 35-mm negatives, our Laboratory prefers a low positive gamma (1.40) yellow-dyed fine-grain untimed 35-mm master positive on such film as Eastman 1365; the one-light master positive is actually much better than the usual mis-timed copy. It so happens that such a master positive may be timed in our plant in making a 16-mm dupe negative in exactly the same way and using the identical timing scale as that for Kodachrome or reversal 16-mm originals. Black-and-white fine-grain release prints made in this way result in excellent gradation, really fine-grain, and a definition and softness that is unknown in direct reduction printing from 35-mm original negatives. (Step picture printing is used throughout.)

Most commercial reduction printers run at too high speed to provide sufficient exposure for fine-grain film; if these printers are slowed down to speeds that will provide adequate exposure, the resulting print is too contrasty for usual positive developers. For direct reduction printing on fine-grain 16-mm films, 35-mm original picture negatives are made to far-too-high gammas for successful use.

SOUND

So far this paper has dealt only with the picture phase of the printing problem; a paper that would do justice to the subject must emphasize sound for the reason that sound can be said to have started it all. To acquire the proper perspective, it is necessary to digress somewhat in considering the subject. It is a well known experimental design trick for an investigator to make scale models of the device he is studying. If the device is something big such as a Mars flying boat or a new super-dreadnaught, he makes small

models that are convenient to study in a miniature wind-tunnel or test-tank. If the device is something small such as a high-quality cutter for disk records, he makes large models so that the action of the various moving members may be studied in more convenient fashion. Knowing the characteristics of the system under investigation, it is possible to predict the performance of the full-scale device from the knowledge of the performance of the made-to-scale model.

In a sense, the fine-grain application problem was similar in its first approximations especially. If 35-mm could tolerate a resolving power of so many lines per mm, 16-mm would require $2^{1/2}$ times that figure. If 35-mm could tolerate so many pounds of muck per million gallons of water, 16-mm could tolerate not more than $1/2.5$ that amount. If 35-mm could tolerate so many pounds of dirt per million cubic feet of air used for drying, 16-mm could tolerate not more than $1/2.5$ that amount. This proved a good starting point.

The 16-Mm Sound Negative.—As in all cases of proportional scalar design, non-linear relationships were found: in simpler language, “bugs.” One of the worst of these was the poor resolving power of film materials used for 35-mm sound recording. The resolving power available was too low for 16-mm; only $1/2.5$ the proportional requirement. There was little hope in conventional films; substantial increases in resolving power resulted in requirements of exposure considerably beyond what could be hoped for in the exposing ability of a 6-volt 1-ampere lamp. At our request, Agfa made a yellow-dyed film (now known commercially as Agfa type 250 high-resolving-power sound-recording film) which worked quite well when exposed through a Jena *BG-12* filter.² The harmonic distortion in the negative was reduced far below that in the usual 35-mm ultraviolet stocks with ultraviolet exposure; in a variable-area negative of density 1.5, for instance, the harmonic distortion of an 85 per cent modulated 400-cycle wave was under 1 per cent, whereas a distortion of about 8 per cent was common in 16-mm ultraviolet negatives. It is well to point out that for more than three years no competitor attempted to market a comparable film; it appeared that no competitor thought it worth while.

Commercial production experience with Agfa 250 for 16-mm sound negatives and Dupont 605 for release prints (variable-area recording) produced a series of incidents indicating that further progress would have to be made without any further attempt to rely

on previous 35-mm experience. Prints of 400-cycle 85 per cent modulated recordings were possible with quite consistent rms harmonic distortion less than 2 per cent. Intermodulation tests of 6000—400 cycles and 4000—400 cycles gave strange results when checked with the harmonic distortion results. It appeared that we had run into a new breed of "bug" with which the industry seems to have had no previous experience.

One odd phenomenon of this new breed is worth mentioning. Suppose that a conventional sound negative is recorded in which there is a voice together with a musical background. By making a print in one manner, the subjective level of the music is raised with respect to the voice; by making a print in another manner, the subjective level of the music is lowered with respect to the voice. Both prints, when compared, are quite "clean" by today's highest commercial standards, yet the difference in subjective level of the music referred to that of the voice seems as much as 10 db in the two prints. If this phenomenon were to occur in Hollywood, it would certainly lead to much disagreement between a re-recording mixer man and the director if either should depend upon the sound from the monitor horn at the time the take was actually made.

This phenomenon has its caution lights; the character of the distortion is audibly different in one kind of print from that in the other. Unfortunately we have found no magic formula to provide an unequivocal answer as to how a print shall be processed; neither intermodulation nor harmonic distortion tests alone are reliable. As George Friedl used to phrase it at our Standards Committee meetings, "It is a matter of how we prefer to have our sound distorted."

A common characteristic of distortion in improperly processed 35-mm variable-density prints is harmonic distortion, yet with 16-mm fine-grain variable-density prints we have encountered some outstanding examples of whistling sibilant distortion that are ordinarily associated with variable-area records. Similarly, while the common distortion characteristic of variable-area 35-mm records that are improperly processed is envelope distortion, we have encountered some outstanding examples of raspiness due to harmonic distortion with little evidence of envelope distortion. With the materials described in this paper, however, both envelope distortion and harmonic distortion are at a minimum, and are somewhat below the distortion levels in current 35-mm feature prints released to theaters.

It is no longer possible to classify a sound recording as variable-

area or as variable-density merely by the character of the most apparent audible distortion. If noise levels and distortion levels are to be further reduced, as they should be in the near future, new techniques will have to be evolved; they may take into account even the character of the sound to be recorded. It is no longer possible to specify the optimal density of a print from a sound negative by merely applying a rule of thumb; a specification that requires such material or a laboratory that produces it will soon show all too plainly that the industry has been accelerating rapidly out of the rule-of-thumb era.

16-Mm Sound Negative Materials.—Within the past year, Eastman Kodak has released EK 5372, a blue-dyed film which is functionally similar to Agfa 250. EK 5372 is definitely “faster” than Agfa 250 when exposed in a Maurer 16-mm sound recorder. For that reason it is convenient to use, but sufficient data are not yet available to determine whether the increase in speed is not gained at the expense of too great a loss of resolving power. For ordinary purposes, the practical differences do not seem large.

Conclusion.—In the earlier part of this paper, it was pointed out that a desirable “ideal” would be to use materials of resolving power of $137\frac{1}{2}$ lines per mm or greater. Under practical conditions of operation, it is likely that our Laboratory approaches this figure with the duplicate negatives. The release-print material falls somewhat short, although the conditions realized in practice are better than the published data. These materials and the technique of handling them result in 16-mm print quality of the very highest commercial standards. Film processed in this manner is more than adequate for picture projection with the best 16-mm lenses in the best 16-mm projectors. With regard to sound, the significant improvement resulting from the engineered use of fine-grain materials is not so much the extension of the frequency range (together with the reduction in noise, hush-hush, and other equally obvious and readily recognized factors) as the reduction of distortion to levels far below those expected from “scale-model” considerations of 35-mm apparatus and materials.

There is plenty of work to be done to boost the quality level of an “average” 16-mm performance. Today we are using film materials whose resolving power is comparable with that of the lenses of better-grade projectors: 80 lines per mm. Already there has been significant clamor for revision of this figure upward although it was con-

sidered satisfactory only a year and a half ago. Materials with resolving power of 100 lines per mm were available in 1931; 150-lines-per-mm material is available now. The technique of manufacture of the latter material is fairly well known; the problem is to prepare to process this material commercially and to bring the price to lower levels by making the use of such material the rule rather than the exception. This, it seems, is the next hurdle for progressive laboratories to jump regardless of whether they process 100,000 feet or 100,000,000 feet per year.

Good film can be obtained now; the film manufacturers are prepared to help any laboratory that is interested by providing information as to the highest-resolving-power materials they sell and the manner of effectively using them. The major step that is missing, and which can be readily taken if there is a serious and honest interest in quality, is the requirement in all Government specifications that any release print will be rejected if in test under actual conditions of use it shows less than 100 lines per mm; any duplicate negative will be rejected if in test under actual conditions it shows less than 110 lines per mm; and any master positive will be rejected if in test under actual conditions it shows less than 150 lines per mm. Any test to be valid shall be a continuous part of the film under test; it shall not be removed from the film. Rejection shall result without further inspection if the specified test-strip does not appear on the end of each film.

These requirements on resolving power will make an excellent starting point; once they have been included in specifications, and rigid and thorough 100 per cent inspection is instituted to assure that the specification is being met, the big step in the direction of quality for 16-mm release prints will have been taken.

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PLANNING FOR 16-MM PRODUCTION*

RUSSELL C. HOLSLAG**

Summary.—The paper discusses production of 16-mm "expository" films—those which explain or instruct. The most important factor involved is the advance planning of an adequate presentation of the subject matter. A direct, simple method of production planning has been evolved and is described, pointing out pitfalls which the beginner should avoid. A shooting-script form, which serves the producer as a combined scenario, shooting script, and editing reference, is described and illustrated. Experience indicates that the teacher or expert who is to guide the production of a training film should give his particular attention to building up a concept; avoiding overextended commentation; having the visual demonstration coincide with the sound-track explanation; showing no action that is unexplained, or no explanation unaccompanied by action; timing the delivery of the commentation; using the full power of the camera; and to treating the audience as an individual novice about to receive instructions through motion pictures.

The term "production" is all-inclusive, and it is not the purpose of this paper to deal with the many aspects of dramatic production or with the planning of films intended for entertainment purposes. The type of production to be discussed is the one in which 16 mm is now especially called upon to perform—that of rapidly turning out films which might be called "expository," films which explain or instruct.

Since there is so much of this kind of film training to be done, we find that the task of planning such films must often be assumed by those who may be thoroughly acquainted with the details of the subject matter of the film to be made, but who may not be so well acquainted with the methods of planning and presentation that will make an effective motion picture. As a matter of fact, the inevitable growth of the expository film will make it necessary for the teacher or expert in any given subject to produce the film, rather than the motion picture expert. The educator will therefore find it necessary to learn enough about the needs of the film medium to present this instruction effectively, just as he must be able to describe his subject logically and clearly in writing if he wishes to write a text-book. And as the writer of a practical text-book need not, and usually does

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not, indulge in colorful word painting and imaginative prose to make his message attractive, the practical producer of teaching films need not feel himself called upon to adopt the dramatic devices that belong to the entertainment field.

Confronted by a motion picture project, the specialist with a thorough knowledge of his subject may be at a loss as to how to organize this knowledge along lines which will (1) enable the actual shooting to be carried out with a minimum of lost motion and waste of time; (2) arrange the material so that the cutting and editing do not present any unusual problems; and (3) include only the material necessary to produce a direct, straightforward result.

Since thoroughly adequate results, both in picture and sound, may now be obtained with existing 16-mm apparatus by any intelligent person who will take the trouble to familiarize himself with the necessary instructions, it follows that the most important factor involved is really the advance planning of an adequate presentation of the subject matter. Through a great deal of direct experience with this type of user of 16-mm apparatus, and through a general review of what seems most in need of emphasis, there has been evolved what is believed to be a direct, simple method of production planning. If this method is carefully followed, experience has shown that results in the production of expository films are quite adequate, even when they are made by those who have not had any particular experience with the motion picture as a medium of exposition.

The planning schedule, as devised, assumes the use of a sound commentary to accompany the visual presentation of the subject. Because of the fact that there are very few occasions where spot-recorded sound is necessary to add to the actual teaching value of the film, the plan makes provision generally for the later addition of a proper commentary after the film has been edited and the breaks smoothed out. Spot-recorded sound can in many cases add to the dramatic value of the film, but this is generally apart from its straight training value.

Many who are called upon to plan their own specialized training motion pictures for the first time have only the model of theatrical motion pictures as precedents which tend to confuse the issue. In view of the pressing need for good training motion pictures at the present crucial time, we may safely assume that our pictures will be given attention by any audience which hopes to benefit from it, without unnecessary dramatic devices. This applies to fancy transitions, trick wipes, mood music, elaborate introductions and conclusions,

entertaining animation sequences and other methods used in theatrical or persuasion films to compel the attention. In view of the seriousness of the situation in which training films are now called upon to serve, it is felt that they need not entertain any more than an instruction book entertains.

Another tendency which should be avoided in advance is over-elaboration and its corollary, the attempt to include too much material in each film unit of the subject under consideration. This is generally the result of the specialist's great familiarity with his subject; that is, he is apt to assume that many points of the explanation are obvious and so need not be emphasized. This is a particularly dangerous conception in the case of a motion picture presentation, because a given action should always be followed through to its conclusion to avoid a jumpy effect. If this principle is not observed, the action when photographed may leave many fundamental points unexplained. The result will be an attempt to supply the missing explanation by means of the commentation alone—an attempt that will usually leave the announcer breathless and the audience bewildered. The only real remedy is replanning and retaking.

Another pitfall to be avoided is often brought about by the planner's literary ability. Many authorities can write clear, lucid explanations of their subjects and are apt to feel that they can create a successful training film by writing a good literary commentary, letting the picture simply trail along at its heels. This, of course, does not take into account the effective combination of action and explanation of which the motion picture is capable. In addition, there is always the danger of writing too much with the result that the action has to take place too quickly to keep up with the rapid explanation. On the other hand, a companion danger occurs when it is planned to photograph the operation in advance in as many aspects as possible; then to edit them and to try to fit them into a smooth-running commentary. This nearly always results in action which is either too short or too long for the proper flow of explanation.

In practice the best results are gained when the visual impression is created coincidentally with the explanation or comment, the latter not involved or verbose but simply describing the action that is proceeding at the moment. Keeping this principle in mind is a real aid in planning both the visible and audible components of a training film together, thus making it fulfill a direct purpose. It is also a great help in overcoming the temptation to be too literary in writing the commentation.

One of the very practical methods for sketching out the plan of an instructional film is to make a verbatim transcript of the explanation, and resulting questions and answers, involved when a beginner is actually introduced to a new process by an instructor. This would apply with equal force to almost any subject, from the handling of a hammer and chisel to the assembly of a complicated mechanism. The information given, the questions asked, and the interval of time between questions provide a valuable index to the amount of material that should be covered in a given time on the screen.

As to the mechanical transfer of the idea material to its most convenient form for the preparation of picture and sound-track, there has been developed a simple form of "shooting script" which at least has proved successful in a number of cases where training film had to be turned out speedily. It serves as a combined scenario, shooting script, and editing reference. By a simple understanding of the points

FILM TITLE: *HAND FORGING* SUBJECT: *QUENCHING & HARDENING*

SCENE NO.	ACTION	MIN. FOOTAGE FOR SOUND	FOOTAGE SHOT	COMMENTATION	NOTES
21	<i>LS Operator places steel in water, using tongs</i>	$2\frac{1}{2}$	3	<i>We cool it suddenly by plunging in water.</i>	
22	<i>MCU Moving the piece around in the water. inspect once or twice, & remove at end of scene</i>	9	$10\frac{1}{2}$	<i>Notice that we move the piece around in the water as it cools. This prevents the formation of steam bubbles which might cause uneven cooling.</i>	<i>Shoot from <u>above</u></i>

FIG. 1.

already noted, together with a thorough knowledge of the subject to be recorded, a practical and direct shooting plan can be evolved by filling in each of the columns provided in the form given. Fig. 1 shows a sample form typically filled in.

The headings are self-explanatory. Each separate scene—that is, the action photographed during the interval between each start and stop of the camera—is numbered in the left-hand column. The action is described in the second column. The narrow column headed *Min. Footage for Sound* denotes the footage necessary to obtain in the take to permit the full sound commentation for that scene to be added later. The footage shown in the next column is filled in immediately after the take and must not be less than that shown in the previous column. In a picture planned along the lines recommended, it is usually more. The actual wording of the commentation is found in the next column. This, of course, will be added after the picture editing is completed. If it is necessary to have any

given point in the action match with a given word in the commentation, it will help to have the words read aloud during the rehearsal and also during the take. The footage needed for a given number of average words in a commentation may be calculated roughly by allotting about three words to each foot of film ($1\frac{2}{3}$ seconds at a film speed of 24 frames per second). In the average 400-ft film unit there are approximately 40 to 50 scenes.

The final column headed *Notes* will take care of any special data that actual shooting conditions may bring about. This will also provide space for notations on retakes. In general, at least two takes should be made of every scene, and preferably three. This usually seems unnecessary to the film maker without much experience, but it is the best form of insurance against retakes which otherwise may be found lacking only after the editing is completed. Each scene should be carefully slated and, in editing, the first rough draft of the finished picture should be made from a work-print, leaving the slate identifications in the film until all final editing decisions have been made.

The shooting script form (Fig. 1) should be typed or multigraphed so that the long dimension of the sheet is horizontal. Multiple copies should be provided and copies in active use should be bound. A copy is given to the cameraman for study and actual use, a copy goes to the supervisor of production, while other copies, of course, are kept for records. Experience in this kind of shooting has shown that it is advisable, as far as possible, to take each scene in the sequence in which it is shown on the script. With large studio production facilities, it is feasible to group together all convenient scenes, regardless of their sequence. But for simple training films not involving extended locations, less confusion will result if the scenes are shot in a straightforward order, one by one.

With this form as a guide, the specialist producer is now ready to work out his script in a logical form. Keeping in mind the desirability of a straightforward, direct approach and avoiding the pitfalls outlined, he will select a portion of his subject and proceed to fill in a trial script to ascertain its probable length. It would be well to confine a first attempt to a subject within the length of a 400-ft unit which will be found to average about fifty scenes.

In visualizing the subject for motion picture presentation, the film planner can proceed most rapidly by imagining a situation in which he is actually showing a beginner how to work with the material illustrated. He must conceive his screen audience as the embodiment of the beginner. Since most specialist teachers have had this experi-

ence, this would seem the best introduction to the method of presentation. Experience of this kind will indicate the questions that will be asked and also what parts of the subject are to be emphasized.

In planning a logical sequence of scenes with the above in mind, the arranger should always keep before him the inherent flexibility of the motion picture camera as to *viewpoint*. The camera brings to the entire audience the visual impression gained by a single individual who must be imagined as receiving the instruction. Just as this individual would have complete freedom to look at the subject closely, or to gain an impression of the whole thing by stepping back, so the camera can emphasize or generalize by means of the long shot and the close-up. As the individual's attention is constantly directed to the various details, the camera may also record a constant variety of shots as the explanation proceeds.

This will be found a satisfactory method of estimating lengths of scenes, changes of viewpoint, and the logical progress of one scene to the next, which is called continuity. No claim is made that this planning process will give an automatic knowledge of the scope and limitations of the camera work itself, for the planner must consult his cameraman at all times and on all points to find out what the camera *can* and *cannot* do. In general, however, he will be agreeably surprised to learn that the camera can show plainly everything a beginner can see, and he will find, in addition, that the camera can often go beyond this and can present things that are ordinarily unseen, even to abstract conceptions.

In brief, experience indicates that the teacher or expert who is to guide the production of a training film should give his particular attention to the following points:

(1) Do not omit any important step in building up a concept, no matter how simple.

(2) Do not write a commentation that is overextended.

(3) Have the visual demonstration coincide in all cases with the sound-track explanation.

(4) Show no important action that is unexplained, or no explanation unaccompanied by action.

(5) Time the delivery of the commentation carefully in advance while mentally or actually rehearsing the action.

(6) Take full advantage of the concentrating power of the camera through the use of closeups.

(7) Consider the audience as an individual who is to receive instructions through the film in the same way as a beginner.

PRECISION RECORDING INSTRUMENT FOR MEASURING FILM WIDTH*

S. C. CORONITI AND H. SCOTT BALDWIN**

Summary.—The paper discusses a mechanical electronic device which continuously measures the width of film to an accuracy of 0.002 mm. The basic circuit is quartz oscillator having a L.C. circuit which is slightly detuned from the resonant frequency. The percentage detuning gives a measure of the film width. Curve shows that for a film variation of 0.250 mm the relationship between film width and measurable current is linear. An inexpensive 0-1 milliammeter can be used without sacrificing accuracy.

Precise measurement of film width is of direct interest to cinematographers, laboratory technicians, and projectionists only so far as it assists the equipment designer and the film manufacturer to provide them with materials that will give optimum performance at all times. With standard equipment and film of standard dimensions, the creative branches of the film industry can direct their energies toward production of the finest pictures, unimpeded by technical problems that were inescapable some years ago.

Motion pictures, especially 16-mm films in which minor dimensional variations are of relatively greater importance than in 35-mm films, are being used increasingly for scientific investigation and the automatic recording of data in industrial operations. In such work, problems in connection with film steadiness and dimensional characteristics, which would not arise in normal motion picture production, sometimes assume an importance that calls for dimensional measurements of the utmost accuracy.

The exact control of width during manufacture of 35-mm, 16-mm, and 8-mm film has always been a problem in the photographic industry. Obviously, before any effective measures for control can be adopted, it must be possible to measure width of the film most accurately to determine the nature and extent of variations which, in turn, serve as clues to factors causing deviations from the norm.

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All common types of motion picture film consist of an emulsion coated on a thin cellulose ester base (approx. 0.005 inch). The material is extremely flexible at this thickness, and this flexibility virtually precludes the usual methods of measuring, as with the micrometer or minimeter, if measurements are to have the desired precision. Added to the difficulty presented by the physical characteristics of film itself are the very small tolerances to be maintained. Table I lists the SMPE Standards and allowable tolerances for cutting 35-mm, 16-mm, and 8-mm raw stock.

TABLE I

	Mm.		Inches
35-mm	35-mm	+ 0.000	1.378 + 0.000
		- 0.05	- 0.002
16-mm	16-mm	+ 0.00	0.630 + 0.000
		- 0.05	- 0.002
8-mm	8-mm	+ 0.00	0.315 + 0.000
		- 0.08	- 0.003

The average variation that can be allowed, therefore, is 0.002 inch or 0.07 mm.

Other points to be considered in controlling the width of films are the quantity and the lengths involved. Nearly all 35-mm films are furnished in 1000-ft rolls, and 16-mm films are available in the same length, although 400-ft rolls are more common. Eight-mm films are furnished in shorter lengths, but regardless of length, every roll must be controlled with accuracy to be sure that the width does not show variations in excess of allowable tolerances. From these considerations, the need for an instrument that will quickly and accurately measure the width throughout long lengths of film will be obvious.

Present Method of Measuring.—At the present time there are two general methods used in measuring the width of motion picture films: one utilizing optical instruments, and the other requiring mechanical instruments of rather familiar type. Of the optical instruments for precision measurement, the Zeiss Comparator and that made by Jones & Lamson are most familiar. In construction, both these instruments are accurate to the fourth place in millimeters, but owing to practical considerations, this accuracy is not realized in film width measurements. In fact, for the purpose, optical instruments present disadvantages in respect to time consumed and continuity of measurement. For accuracy, each section of film must

be cut from the roll and adjusted on the viewing stage before measurement, the entire operation requiring approximately five minutes. It is not possible to read width variations continuously throughout the entire roll and the time required for individual readings becomes a major factor.

For measuring film width by mechanical means, the micrometer or the dial-gauge type of instrument may be used, but neither is very satisfactory. The former can not be used to obtain precise measurements because pressure against edges of the film, required for an accurate reading, is great enough to make the film buckle, and the time required for measurement is as great as with the optical instruments. Use of the dial-gauge instrument involves also considerable pressure against edges of the film, and mechanical amplification of movement imparted by variations in film width is not sufficiently even to give readings of greatest accuracy. Adequate maintenance of these instruments presents also a definite problem in routine production control.

Consideration of the problems that arise in using conventional optical or mechanical instruments warrants the following conclusions:

- (1) Dependence upon operative skill for accurate positioning of the specimen makes measurement tedious and frequently inaccurate.
- (2) Instruments requiring relatively forceful contact with the object to be measured, for accurate readings, are unsuitable for measuring fragile, thin, or very flexible materials.
- (3) Amplification of movement imparted to a measuring instrument by means of mechanical linkage is seldom sufficiently reliable for the utmost precision, and maintenance is a considerable problem in routine production work.
- (4) Continuous measurement of the width or thickness of an unbroken strip of material, with extreme accuracy, great rapidity, and with automatic recording of dimensional changes, has hitherto been but a dream of production engineers, without hope of realization by use of existing instruments.

Assuming that the specimen could be positioned for measurement in reproducible manner, without skill on the part of the operator, and that very light contact with the gauge would suffice for measurements of the greatest precision, it is apparent that an instrument actuated by mechanical contact with the specimen would be most convenient for determining the exact width or thickness of a motion picture film. Although physical contact between the film and the gauge does simplify the use of an instrument, the micrometer principle must be abandoned if rapid action is desired and mechanical

amplification is not entirely reliable for accurate work. With these points in mind, certain fundamental characteristics of a suitable instrument may be listed as follows:

- (1) Film to be in physical contact with guide for positioning specimen, with physical contact between film and variable member of the gauge.
- (2) Linkage between the variable member of the gauge and the indicator is to be practically frictionless and free from inertia or irregularity of action at any position within the measuring range of the instrument.
- (3) Mechanical construction is to be simple, rugged, needful of minimum maintenance, and not easily damaged.

Following a thorough study of the problem and the principles and limitations of available measuring instruments, all three of the essential characteristics listed above have been incorporated in a new electronic film-width gauge, characterized by simple mechanical construction and a stable electrical circuit, which eliminates mechanical linkages by electronic amplification. This allows the continuous automatic measurement and recording of film width, rapidly and with precision heretofore attainable only by skilled operators using the most accurate optical instruments.

The electronic width-gauge gives measurements in agreement with test-blocks and with the stereo comparator, but readings are reproducible within 0.002 mm, a degree of accuracy somewhat beyond that attained by operators using the stereo comparator. With minor changes in construction, the electronic width-gauge can be adapted to give width or thickness measurements of requisite precision for many other applications in science and industry.

The essential mechanical element of the film-width gauge is a small lever, about 2 inches long, swinging on a bearing about one-third the distance below the upper end. At the upper end of the lever, a rounded surface presses lightly against one edge of the film as it passes through the gauge. If the film becomes wider, the upper end of the lever is pushed outward, and since this is above the fulcrum, the lower end of the lever swings inward. As the lever swings, a metal disk at the lower end moves nearer to, or farther from, a similar disk which is fixed and immovable. These two metal plates never actually touch one another, but as the distance between them varies with variation of film width, they actually constitute a variable condenser.

With change of film width there is a change in capacitance of the variable condenser, and this change is amplified electronically, giving

instantly a direct reading or recording of film width in millimeters. Thus, with but one moving part in the actual measuring mechanism, variations of film width are measured in a fraction of a second, and the most minute changes are amplified to a degree allowing clear and easy reading, without injury to film from pressure of the mechanism.

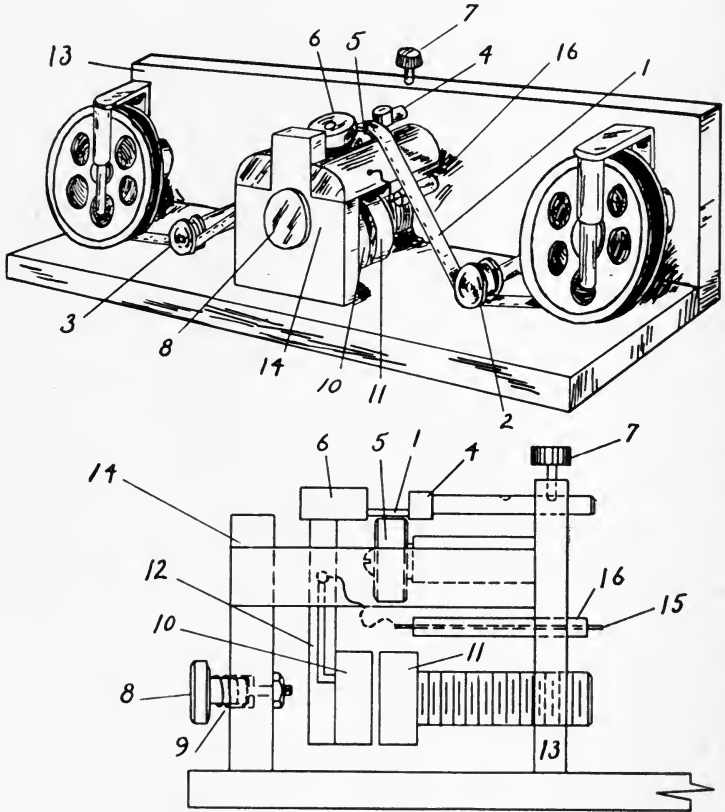
Mechanical Construction.—Fig. 1 is an oblique view of the electronic width gauge, showing the important mechanical features of design. Film 1 passes from the feed roll, under guide-roller 2 through the measuring head under the second guide-roller 3, and to the take-up roll which is driven by a motor, not shown. Guide rollers, measuring head, and spindles for the film rolls are all constructed so that 8-mm, 16-mm, or 35-mm films can be measured interchangeably.

The measuring head consists of the fixed lateral film guide 4 which is adjustable for any standard width of ciné film, the ball-bearing film-supporting roller 5, and the movable lateral film-guide 6 which is attached to the swinging lever, with the movable condenser plate attached to the lower end. The immovable lateral film-guide 4 can be adjusted for different widths of film by lifting the lateral positioning-pin 7 and moving the film-guide 4 until the proper space separates it from the other film-guide. Then, by lowering the tapered positioning-pin into a tapered hole, the guide 4 is firmly locked in position. This tapered design of the locking mechanism insures the same positioning of the fixed lateral film-guide whenever it is adjusted to measure film of any particular width, regardless of intervening adjustments for other widths of film.

As the film passes through the measuring head, it is curved over the ball-bearing film-supporting roller 5. The path described by the film in passing over this roller forces it into a partially cylindrical contour at the point of measurement, thereby inducing lateral rigidity and assuring that the true width of the film will be measured. This simple method of film-guidance is one of the prime factors insuring accuracy and reproducibility of readings with the instrument.

The zero-set button 8 (Fig. 2) is used for adjustment of the instrument, if necessary. Depression of this button, against the tension of the return spring 9 shifts the movable condenser plate 10 to a definite predetermined position in relation to the fixed condenser plate 11. When condenser plates are separated by this predetermined distance, the lever and movable film-guide are in a position corresponding to that which they would occupy if a film were of

exactly the specified width, and neither wider nor narrower. When measuring such a film, the instrument should give a zero reading, and if there has been any slight drift from the correct setting, this can be determined and corrected immediately. In effect, the zero-



FIGS. 1 AND 2.

set button serves the same purpose as a standard test-block for calibrating the instrument, but it eliminates the inconvenience of separate gauges which might be lost or damaged.

In designing the electronic film-width gauge, to eliminate errors of the kind inherent in mechanical devices for precise measurement, moving parts were restricted to the single pivoted member con-

stituting the lever. This lever is pivoted off center, thereby creating a constant pressure of $1\frac{1}{2}$ ounces against the edge of the film.

The only parts on the instrument subject to appreciable wear are the two lateral film-guides in the measuring head. Although these are made of specially hardened steel, in time they will become grooved. However, each of these guides can be removed and replaced very easily, and carballoy, sapphire, or other superhard surfaces can be adopted.

Film is moved through the instrument by a small motor with geared reduction. The speed of this motor is variable. The accuracy of measurement is not affected appreciably by variations of film speed throughout the range within which the gauge is designed to operate.

In Fig. 2, any displacement of the lateral film guide 6 by the film 1 is transmitted to the movable condenser plate 10 by the insulated lever 12. The condenser plates 10 and 11 are completely insulated from the mechanical elements of the measuring head.

The fixed condenser plate 11 is grounded to the metal chassis 13 and is held in position by a fine-thread screw attached to it. By rotating this condenser plate, the distance between the two condenser plates can be readily adjusted.

The upright member of the chassis assembly 14, in addition to acting as a support for the horizontal member from which the lever is suspended, acts also as a shield for the movable condenser plate 10. Inasmuch as the instrument acts on a change in capacitance, any foreign metallic object approaching the condenser plate introduces additional capacitance which leads to erroneous readings. A very fine and flexible wire connects the movable condenser plate with a conductive metal rod 15 surrounded by an insulating tube 16 of polystyrene resin.

Discussion of Electrical Requirements.—Small linear displacements have been measured electronically by early investigators.^{1,2} The small linear displacement to be measured was coupled mechanically to a variable electrical condenser in an electronic circuit. Therefore, variations of displacements were translated into changes of plate current, measured by a sensitive galvanometer, or by changes in the oscillation frequency of an oscillatory circuit. Practically both these methods are restricted to laboratory usage. For routine production operations, an instrument must be rugged and accurate. In the circuit described in this paper, the sensitive galvanometer

has been replaced by an inexpensive 0-1 milliammeter, which is rugged and can be used by any unskilled operator.

The resonance circuit consists of an inductor L and two capacitors C_1 and C_2 connected in parallel.

If A is the surface area of the two parallel plates 11 and 12 (Fig. 2) and d is distance between them, the capacitance is given by

$$C = \frac{kA}{4\pi d} \quad (1)$$

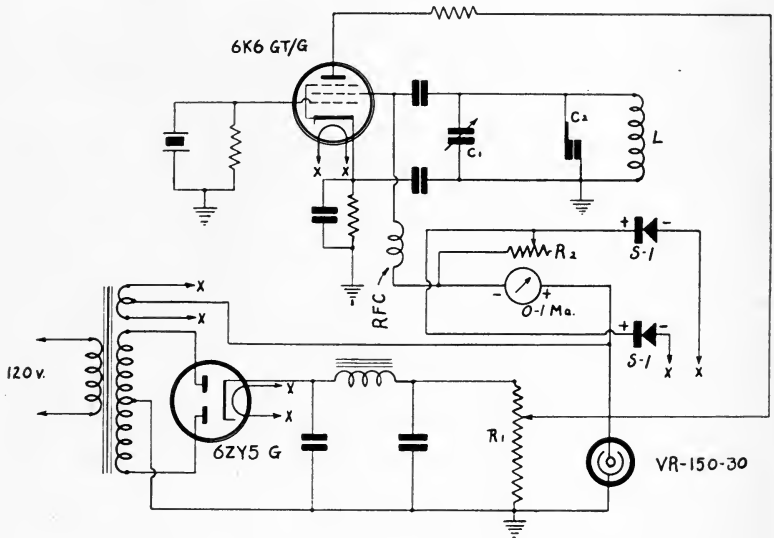


FIG. 3.

If d is decreased by a small distance Δd , the change in capacitance is given

$$\Delta C = \frac{kA}{4\pi d} \cdot \frac{\Delta d}{d + \Delta d} \quad (2)$$

From equation 2 it is seen that the sensitivity of the variable condenser depends upon the distance separating the two plates. By making d very small, the change of capacitance is greater for a given change of Δd . However, in this instrument the minimum distance is limited by the maximum change of film width. If linearity is desired, distance is limited also by the change of slope of equation 2. For very small values of d , the change in capacitance is greater

for negative values of Δd than for equally positive values, and a minimum distance d can be found that will yield a negligible percentage of error for small $\pm \Delta d$ variations.

The average variation of width in 35-mm, 16-mm, and 8-mm films, permissible within tolerances established by SMPE standards, is 0.07 mm. In the present instrument, the areas of condenser plates and the distance between the plates are such that the change of capacitance to be detected is extremely small.

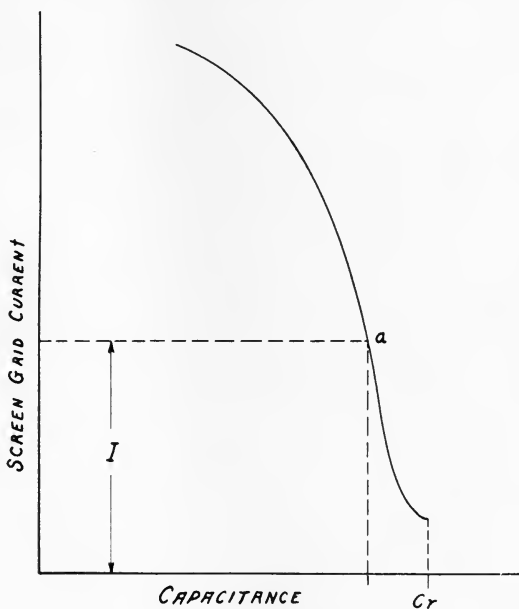


FIG. 4.

Small variations of capacitance can be measured conveniently by their effect upon the frequency of an oscillator circuit or by their effect upon the amplitude of current in a parallel resonance circuit. Fig. 3 is a diagram of the present electronic width-gauge. Essentially it is a fixed vacuum-tube oscillator loaded by a variable parallel tuned circuit, the impedance of which varies with the capacitance fluctuation of the mechanical condenser C_2 . As a result, the direct current flowing through the vacuum tube varies, and these variations are directly proportional to variations in width of the film or other object being measured.

The capacitor C_1 is a fine control to compensate for minor fluctuations in frequency. If reproducible results are desired, it is extremely important that the resonance at which the circuit operates be confined to one point on the resonance curve. Assuming that the overall capacitance is changed by a very small amount to some value less than that required, the change of current for a given change of capacitance will be less because of the non-linearity of the resonance curve. If the curve were linear, the drifting of the operating point caused by a change of capacitance would not introduce errors into the measurements.

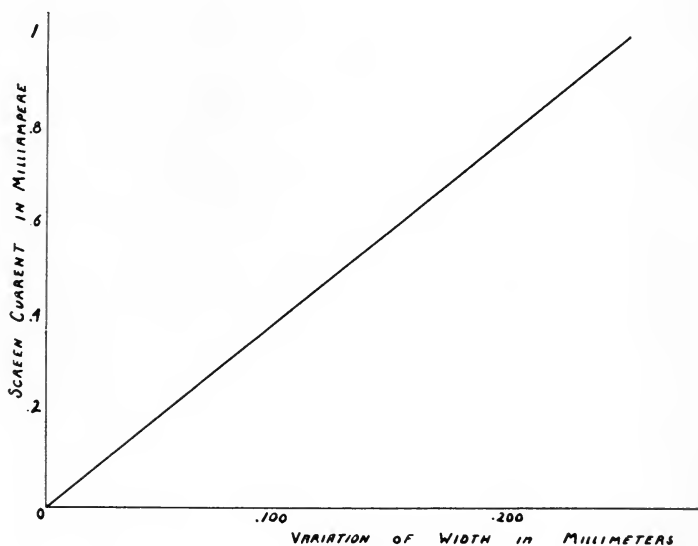


FIG. 5.

The source of oscillation is a quartz crystal connected to the grid of a $6K6GT/G$ vacuum tube. The parallel resonance circuit is connected to the screen grid, a feature of design leading to increased stability of operation. The plate and screen grid are operated at half their rated voltages. Power supply is a $6ZY5G$ full-wave rectifier with a $VR-150-30$ connected across a fraction of the bleeder resistance R_1 . The screen is fed by a shunt consisting of an r. f. choke, a 0-1, d-c milliammeter or 0-1 d-c recording milliammeter and a rectified source of voltage which is used to balance out the normal current flowing in the screen.

This rectifier circuit consists of two small selenium rectifiers S_1 , which feed a variable resistive load. The source of power for this circuit is the voltage across the rectifier filaments, and no additional filtering is necessary. A half-wave rectifier was not used in this circuit because it caused vibration of the recording stylus.

The component units of the electronic circuit were selected to minimize the generation of heat, for it is known that the impedance of a tuned circuit and of the tube elements are functions of the surrounding temperature. Accordingly, the screen-grid current will fluctuate if the necessary precautions are not observed to prevent fluctuations of temperature. With the present circuit, after approximately five minutes for heating, no drift in screen-grid current

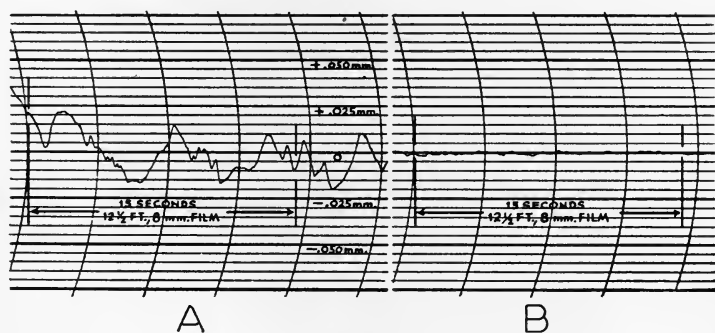


FIG. 6.

was noticed during continuous operation for 48 hours. The stability of the circuit is excellent.

Operation of the circuit is illustrated graphically in Fig. 4, which shows the relation between screen-grid current and capacitance of the resonance circuit. In a crystal oscillator circuit, the resonance curve is not symmetrical, one side of the curve having a slope much greater than the other. This effect is caused by the influence of the tuned circuit upon the crystal impedance.³ When film is held between the fingers, as in threading the width-gauge, the capacitance is varied so the circuit is no longer in resonance, as indicated by a or some other point on the curve. The direct current I corresponding to point a is balanced until the meter reading corresponds to the desired reading on the scale. As the width of the film becomes greater or less than the width corresponding to a zero setting of the width-gauge, the meter indicates a flow of current greater or less than the

value represented by the point *a* on the curve. Once this point for correct operation has been determined, calibration of the instrument becomes simple. The zero position on the meter is checked occasionally by pressing the zero-set button 8 (Fig. 2).

The difference in current can be materially amplified by simply increasing the efficiency of the resonance circuit, that is, by increasing

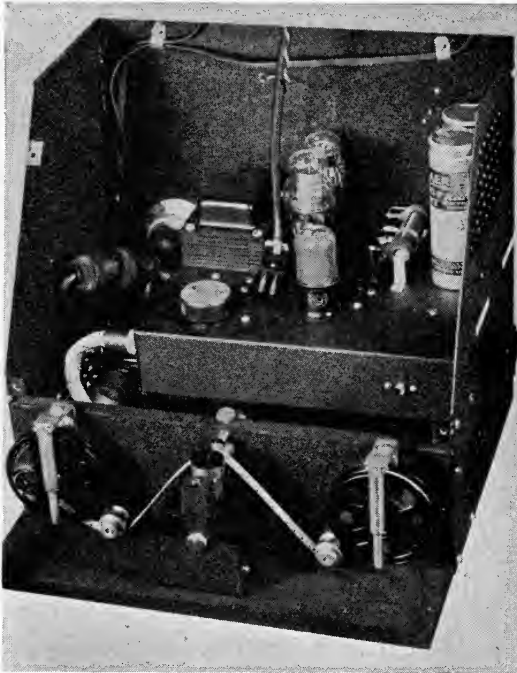


FIG. 7.

its *Q* value. The sensitivity to small changes of capacitance can be increased also by increasing the frequency of the generator.

For linear differences of current with changes of capacitance, the circuit should be operated on the part of the resonance curve where the change of slope is zero. With only small changes of capacitance, such a portion of the curve does exist for practical purposes. In the present instrument, this portion of the curve corresponds to a linear response for changes of capacitance effected by variations of film width not exceeding 0.25 mm. Fig. 5 is a curve obtained by measur-

ing known widths of 8-mm film and plotting the values against the current response. The curve shows the linearity of the circuit.

By replacing the d-c meter by a recording milliammeter, such as that made by the Esterline-Angus Company, Inc., continuous automatic recording of variations in width can be achieved. The speed of the recording chart and of the film can be adjusted to suit the convenience of the operator.



FIG. 8.

Fig. 6 shows a section of the record of width variation in a 50-ft roll of 8-mm film. *A* shows a maximum width variation of 0.045 mm, and *B* shows a maximum width variation of 0.002 mm.

Fig. 7 is a photograph of the complete electronic film-width gauge, opened to show its component parts. Fig. 8 shows the case when closed, with a 0-1, d-c milliammeter, calibrated directly in millimeters.

Reproducibility of Results.—It is very necessary that a control instrument be reliable. It must give accurate and reproducible results over long periods of time, with minimum variation. Table II shows a comparison of results obtained with the electronic width-gauge and with the Zeiss stereo comparator. In this test, three points on a strip of 16-mm film, which had been processed and shrunk, were selected at random. Each of these points was read five times by the same operator, using each of the two instruments, and the readings were recorded as follows:

TABLE II

	<i>Electronic Width-Gauge</i>			<i>Zeiss Comparator</i>		
	Point Number			Point Number		
	1 (mm)	2 (mm)	3 (mm)	1 (mm)	2 (mm)	3 (mm)
1	15.866	15.855	15.864	15.868	15.854	15.861
2	15.868	15.854	15.866	16.866	15.854	15.867
3	15.866	15.856	15.867	15.869	15.856	15.868
4	15.866	15.857	15.866	15.870	15.855	15.865
5	15.867	15.855	15.865	15.868	15.855	15.865
Average	15.866	15.855	15.865	15.868	15.855	15.865
Variation	0.002	0.003	0.003	0.004	0.002	0.007

From these tables it is apparent that the electronic width-gauge gives readings of great precision and with reproducibility superior to instruments formerly used for determining film-width. The continuous recording of film-width also has allowed certain studies to be made in connection with the smoothness of slitting, leading to refinements of manufacturing procedure and engineering control surpassing original expectations.

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CONSERVATION OF PHOTOGRAPHIC CHEMICALS*

ALLAN HAINES**

Summary.—A chemical and a mechanical method of conserving photographic chemicals in the processing laboratory are described.

The purpose of this article is to present to the black-and-white photographic processing laboratory a means of conserving photographic chemicals without a reduction in the quality of the product. This conservation is accomplished by a chemical method and a mechanical method.

CHEMICAL METHOD

The chemical method originated several years ago and is currently in successful use by several laboratories which demonstrates its practical value. The method utilizes the excess volume of negative developing solutions, which is normally discarded, as a source of part of the chemicals needed for the positive developing solutions. The principal source of this excess volume is found in the negative-action developer and the variable-density type sound-track developer. Both of these solutions are rich sources of sodium sulfite, and, in addition, the latter is usually a good source of metol and hydroquinone. These three materials represent the most important items in a chemical budget.

There are six essential materials involved in the composition of the various developing baths commonly used in a black-and-white processing laboratory:

Negative-Action Developer	Variable-Density Sound-Track Developer	Positive Developer
Metol	Metol	Metol
Hydroquinone	Hydroquinone	Hydroquinone
Sodium sulfite	Sodium sulfite	Sodium sulfite
Sodium metaborate	Borax	Sodium carbonate
Potassium bromide	Potassium bromide	Potassium bromide
Water	Water	Water

* Presented at the 1943 Spring Meeting at New York.

** Pathe Laboratories, Inc., Los Angeles.

In the above list the alkaline materials (*i. e.*, sodium metaborate, borax, and sodium carbonate) are the only ones not common to the three formulas.

The above alkalis vary in strength depending upon the concentration of hydroxyl ions which each supplies to the solution. If the alkali is strong, as sodium carbonate, it furnishes a high concentration of hydroxyl ions and the pH of the solution is said to be high. If the alkali is weak, as borax, both the hydroxyl ion concentration and the pH of the solution are relatively low.

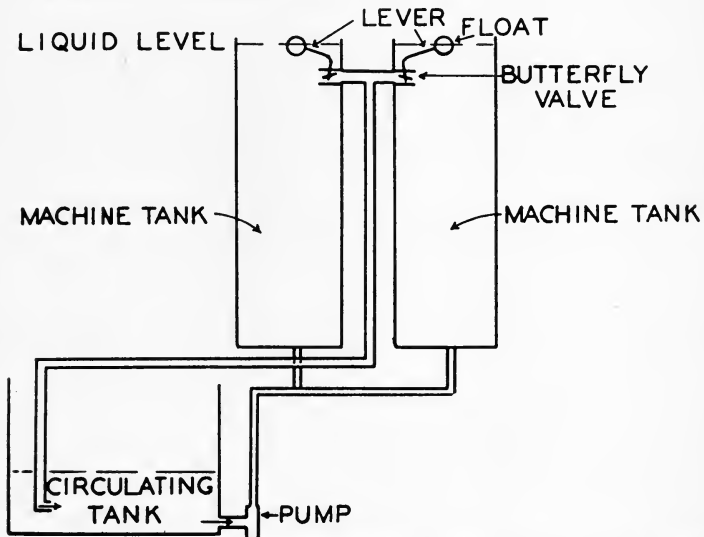


FIG. 1. A typical circulating system with butterfly valve control in the return pipe line.

The developing agents metol and hydroquinone depend upon the pH of the solution in which they are dissolved for the rate at which they form a silver image in a photographic emulsion. It is known that the pH value of a developing solution is one of the most important factors in determining the character of that solution. In general, negative solutions have a low pH value and positive solutions have a high pH value. Therefore, if one raises the pH of a negative-developer solution by the addition of a strong alkali, that solution takes on the characteristic of a positive developer.

The successful utilization of excess developing solution depends upon the application of a systematic chemical analysis in order to show the additions necessary to convert the negative solution to a positive-developing solution. Usually the metol, hydroquinone, or sodium

sulfite will be present in higher concentration in a negative solution than is desired in a positive-developing bath. Therefore, the solution must be diluted with water until the material in highest concentration in the negative solution is at the proper value for the positive developer. From this known dilution can be calculated the additional amounts of the other materials which must be added to give the correct composition.

The next step is to adjust the pH of the solution. Sodium carbonate plus a small amount of sodium hydroxide is used since sodium carbonate alone is not strong enough to give the proper alkalinity to the solution. The amounts of these two alkaline materials which must be used depend upon the activity desired in the positive developer. To insure the proper addition, measurements are made on the solution with a pH meter. The speed of the developing machine depends, to a considerable extent, upon the activity of the developer, and, therefore, the amount of alkaline addition must be worked out to fit the requirements of each individual laboratory.

MECHANICAL METHOD

The mechanical method of conserving photographic chemicals reduces the aeration of the developer while it is being circulated in the developing-machine tanks and reduces the amount of foam formation. Up to ten per cent of the metol, hydroquinone, and sodium sulfite can be lost by aeration by the oxygen in the air. The elimination of foam removes a nuisance and also the necessity for breaking down the foam at intervals with octyl alcohol or a similar reagent.

Aeration of the developer is prevented by adding a float-controlled butterfly valve to the return line of the circulating system in order to maintain a fixed level in the tank. The valve and float automatically meter the amount of fluid flowing out of the tank. Once the length of the lever arm to the float is adjusted, the return flow will remain fixed as long as the circulating pump of the system maintains a reasonably constant output.

Fig. 1 shows a typical circulating system with the butterfly valve control in the return pipe line. The exact arrangement of course will vary with different types of machines. In this particular system 2-inch valves have been found adequate to circulate about 75 gallons per minute of liquid from a machine tank which is about 8 feet above the liquid level in the circulating tank. The relative heights of the machine tank and the circulating tank, as well as the capacity of the circulating pump, must be considered in selecting the proper size of valve.

MAPS ON MICROFILM

SOME FACTORS AFFECTING RESOLUTION*

MICHAEL BRUNO**

Summary.—Results of research on the reproduction of maps in 35-mm color and black-and-white film are described. This research involved a thorough study of the effect of material, equipment, and processing on resolution. Observations of these effects have been carefully studied and the results are presented with a discussion of some of the factors influencing them.

The conclusions drawn from this research are: (1) The reproduction of colored maps in color on 35-mm film is impossible because of the low resolving power of present color emulsions. (2) Reproduction of colored maps in monochrome on 35-mm is not satisfactory because of grain clumping in magnification above 20x. (3) The resolution of an image is a composite function depending on the degree of correction in the optical system producing it, the resolving power of the material reproducing it, and the processing it undergoes.

EXPLANATORY

The research which produced the observations and conclusions described in this paper originated from the desire to reproduce maps in color on microfilm which, on projection onto a translucent screen, would provide a satisfactory substitute for the original map. The success of such a project would offer many obvious advantages—microfilm would conserve space, and reproduction in color would insure accuracy of interpretation.

Maps are complex line patterns in color where each color depicts definite specific information, the loss of any of which would seriously impair their usability and reliability. The order of fineness of detail often extends to six-point, lower-case type, or approximately four lines per millimeter, and in many cases of finely contoured maps it might even approach ten lines per millimeter. The use of color on maps reduces visual contrast, and it is not unusual on some maps to have line patterns or detail in color so fine that they can not be adequately interpreted without the aid of a magnifier. Also, some maps

* Presented at the 1943 Spring Meeting at New York.

** Captain, U. S. Army Map Service, Washington.

are so large as to require a 30x reduction for inclusion on a double 35-mm non-perforate frame.

Hence, the satisfactory production of reduced photographic records of maps involves the consideration and study of two problems; namely, color reproduction and resolution. It was anticipated that some difficulties would be encountered in this project, because

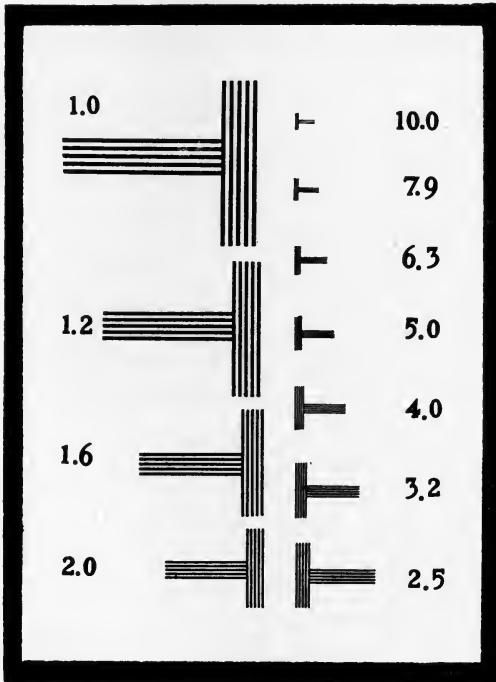


FIG. 1. Resolution target chart.

critical examination of results of test exposures made on three different types of microfilming equipment indicated that these systems did not produce sufficient resolution even for the reproduction of the original maps in monochrome.

Standard microfilming practice has been designed for the photography of originals possessing high visual contrast, but the reproduction of colored maps in monochrome produces areas of low contrast in the negative where resolution is affected by a number of factors. Consequently, it was planned to investigate microfilming practice and

methods thoroughly and endeavor to develop a high-resolution system which would produce a maximum resolution on standard available color media, and in this way determine conclusively the limit of reduction which maps would allow.

EQUIPMENT

To accomplish this and isolate and study the effects of most variables on resolution, a precision photographic system was installed on an optical bench. The system was so designed that lenses could be interchanged, and a movable focus plane was so adjusted that it coincided absolutely with the emulsion plane. This system was used for some time, but in later experiments it was superseded by a specially fitted precision process camera in which the focus plane, lens, and copyboard are mounted on a sturdy, shockproof frame.

The map to be photographed for resolution tests is fitted with resolution charts (Fig. 1) in the center and at the four edges. These target charts¹ consist of ten radial and tangential line patterns, composed of five lines and intervening spaces of equal width, and varying in fineness from one to 10 lines per millimeter. A removable, chemically grained glass plate with a transparent center serves as a focusing screen.

Images are focused with a Lomara portable microscope that has been prefocused on the front surface of the glass. Exposures are made on cut film that is held in the focus plane by a glass plate coated evenly with Stay-Flat solution. This method of supporting the film seemed questionable at first, but numerous checks and reproducibility of results indicate that it is extremely accurate and reliable. Since resolution was the only consideration in this photography, it was decided to use a graphic film of the slow, fine-grain, high-contrast, high-resolution type.

OBSERVATIONS

With this equipment and material, the effect on resolution of developers, exposure, processing, and lenses was observed. These observations have been carefully studied and analyzed, and their results are presented with a discussion of some of the factors influencing them.

Developers.—The effect of developers on resolution was one of the first observations made in this research and the results were very revealing. Since graphic film was used, it was processed in the recommended developer, which is *D-85*, a hydroquinone-paraformaldehyde

developer. Examination of the resolution targets showed effects very similar to those produced by an image out of focus (Fig. 2). The highest average resolution attainable with this developer at recommended time and temperature was 24 lines per millimeter, while the rated resolving power of the material is approximately 100 lines per millimeter. No amount of correction in focus could improve these results.

Consequently, it was suspected that the developer was either causing or contributing to this effect. A change to *D-72* diluted 1:2 with water confirmed this suspicion. At the focal plane established by the use of the Lomara microscope, it was possible to produce with

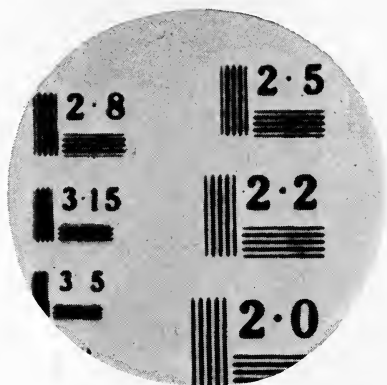


FIG. 2. 25x photomicrograph of negative developed in *D-85*.

this developer on one specific type of graphic film a resolution of 100 lines per millimeter. However, the use of *D-72* produces a troublesome fog density, characteristic of most metal developers, which reduces contrast and interferes seriously with readability. It was possible to eliminate this fog density and retain the resolution by the use of a standard but not commonly known developer, *GD-190* (Fig. 3), the chief ingredients of which are hydroquinone, carbonate, and citric acid.² Several so-called "fine-grain" developers were tried in this research, but none could improve the resolution obtained with *GD-190* and *D-72*.

This observation is theoretically interesting because it seems to refute the statement of Ross and other writers who claim that the composition of a developer has no effect on the resolving power of an

emulsion.³ While this statement was substantiated by the fair consistency in resolution attainable with a number of different types of developers, a definite and serious degradation of resolution was observed with the use of *D-85* and other hydroquinone-paraformaldehyde developers. The only explanation for this phenomenon is that these developers produce such high contrast that they are sensitive only to a narrow range of exposures or subject brightnesses. In the small resolution targets, or in fine detail where the lines are narrow and very close together, there is not enough difference in subject brightness between the lines or patterns to be included in the narrow

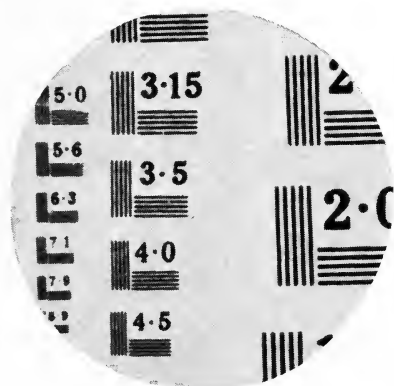


FIG. 3. 25x photomicrograph of negative developed in *GD-190*.

range on which the developer acts, so that the result is a blurred image possessing poor resolution.

This observation has led to important conclusions in process photography for photomechanical reproduction where high contrast is necessary and preservation of fine detail is desirable. As stated previously, hydroquinone-paraformaldehyde developers, as customarily recommended and used on graphic films, are sensitive only to narrow ranges of subject brightness so that they can reproduce copy containing either all coarse patterns or all moderately fine patterns, but can not satisfactorily reproduce copy containing both without emphasizing one at the expense of the other. On the other hand, *GD-190* produces adequate contrast for photomechanical purposes, and it possesses a sufficiently long scale to allow it to reproduce satisfactorily both coarse and fine patterns simultaneously. *GD-190* offers

another advantage in that it possesses a longer useful life and is more consistent in action than developers of the hydroquinone-paraformaldehyde type.

Exposure.—The effect of exposure on resolution has been studied and results indicate that slight improvement in resolution can be gained from overexposure and underdevelopment. It is believed that underdevelopment produces a surface image by not allowing the developer to act on the silver grains in the lower layers of the emulsion; and overexposure activates sufficient grains in the emulsion to produce the desired density and contrast in the surface image. Underdevelopment also has the effect of reducing the graininess of the image⁴ resulting in better resolution.



FIG. 4. 20x photomicrograph.

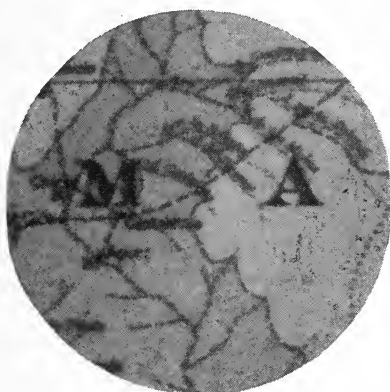


FIG. 5. 30x photomicrograph.

Processing.—The processing of photographic emulsions produces an effect on resolution as a result of its influence on granularity. By processing is meant the handling of the photographic material after exposure, through the development, fixing, washing, and drying stages. The literature is replete with references and recommendations for fine-grain processing, but in this investigation it was observed that even under the most ideal processing conditions, negatives were obtained in which granularity was resolvable at 20x magnification and at 30x was so apparent that it seriously interfered with the line patterns (Figs. 4 and 5).

This phenomenon is the limiting factor in the monochromatic reproduction of colored maps. It is caused primarily by the fact that gelatino-silver halide emulsions are composed of discrete, crystalline

grains of silver halides of varying sizes dispersed in a hydrophilic medium, gelatin. In the development process the gelatin swells, allowing diffusion of the developer, and the silver halide grains activated by exposure to light are reduced to corresponding grains of metallic silver. The gelatin remains in a swollen condition throughout the processing until dried, and any factors which accelerate or retard the rate of swelling of the gelatin promote the agglomeration of the silver grains into unsymmetrical groups, or clumps, producing granularity.⁵

The more important factors which affect the rate of swelling of gelatin include temperature, time, pH, and composition of electrolytes,⁶ and unless these are controlled the effect of granularity becomes serious. This effect is believed to be the result of reticulation because, theoretically, in negatives developed to the same density and gamma the conditions under which processing is conducted should have no effect on granularity.⁷

It is known that the effect of grain clumping is most apparent in areas of low and medium density.⁸ In areas of high density, where the silver halide grains are completely activated by light, grain clumping disappears; or rather, it progresses to the degree that the clumps overlap, leaving no clear spaces between them. High contrast originals can, therefore, be reproduced with a minimum of granularity, and it is this fact which is responsible for most of the success enjoyed by standard microfilming practice.

Lenses.—The effect of lenses on resolution was studied exhaustively because it is unquestionably the most important direct factor influencing resolution. Many lenses were investigated in this research and several important observations resulted which are not specifically described or adequately explained in the literature. Among the lenses tested were a 50-mm Eastman *Ektar*, a 63-mm Goerz *Dagor*, a 4-inch Goerz *Apochromat Artar*, a special 195-mm Eastman *Ektar f/4.5*, a 24-cm Zeiss *Apotessar*, a 12-inch and a 19-inch Goerz *Apochromat Artar*. All of these lenses are of the well-corrected process design and they were specially selected so that as a whole they represent approximately the highest degree of precision attainable in this range of focal lengths.

The 50-mm *Ektar* was a fixed aperture lens and under ideal processing conditions it produced negatives on microfilm with a resolution of 120 lines per millimeter on the axis and 95 lines per millimeter at 15° off the axis. All the other lenses possessed variable apertures, and

exposures at full aperture showed higher resolution on the axis than at 15° . Also, the axial resolution for all the focal lengths up to and including the 24-cm *Apotessar* was approximately the same, but that of the 12-inch and 19-inch *Artars* was progressively lower. Decreasing the aperture in the focal lengths through the 24-cm *Apotessar* caused a slight loss in resolution on the axis and an appreciable increase at the edges of the field. In stopping down the 12-inch and 19-inch *Artars*, the overall resolution was improved, the edges improving at a faster rate than the center up to a specific aperture, after which the axial resolution suffered a loss which increased as aperture decreased.

These observations indicate, for well-corrected lenses of similar design, the existence of two types of lens behavior depending on focal length. An explanation of this requires the consideration of the factors influencing the formation of an image. This is best done by dividing the image into axial and outer zones and considering the effect of optical phenomena in each zone.

Assuming good color correction, the resolution of the image on the axis is determined by spherical aberration and diffraction. Generally, in long-focus lenses of moderate apertures, resolution on the axis is limited by spherical aberration, while in short-focus lenses it is limited by diffraction. In the range of focal lengths where the resolution is controlled by diffraction, a change in focal length does not change the resolution, but in the range where it is controlled by spherical aberration, an increase in focal length causes a decrease in resolution.

If the resolution of a lens is limited by spherical aberration, as in the case of the 12-inch and 19-inch *Artars*, it can generally be improved by decreasing the aperture, eliminating the marginal rays that cause the effect of spherical aberration. There is a limit to this stopping down, because when the aperture approaches a size where it is affected by diffraction a loss in resolution will result. In any case, the best resolution attained is less than that of a corresponding lens of shorter focus for which the resolution at full aperture is limited by diffraction. In these lenses, decreasing the aperture increases the diffraction, resulting in a loss in resolution. A comparison of these facts with results observed in this research indicates that the lenses up to and including the 24-cm *Zeiss Apotessar* can be considered in the class of short focal lengths affected by diffraction, while the 12-inch and 19-inch *Goerz Artars* are long-focus lenses limited by spherical aberration.

The consideration of the outer zones of the lens offers several com-

plications. As a general rule the resolution in the outer zones of a lens is poorer than it is in the center. This is caused chiefly by curvature of field. This aberration indicates that when a flat surface perpendicular to the axis of the lens is photographed, the image is not a flat surface but is a surface of revolution with a bulge away from the plane of focus (Fig. 6). The amount of bulge or departure from emulsion plane is directly proportional to the focal length in specific lens designs. The presence of this bulge in the focal surface prevents coincidence of the focal surface and emulsion planes in the off-axis areas of the image, resulting in damage to definition or resolution of the image in these zones. Decreasing the aperture increases the depth of focus

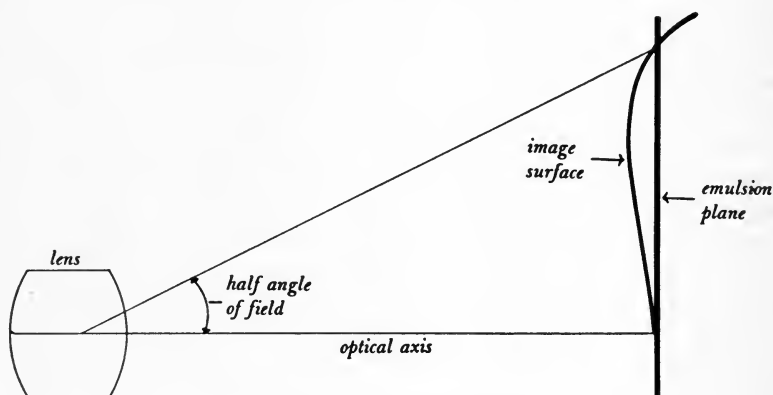


FIG. 6. Curvature of field.

of the lens, effecting an improvement in resolution in the outer zones. There is a limit to this improvement caused by the complex effect of diffraction on the image points in this zone when apertures get too small.

From this discussion, the selection of an optimum working aperture to produce maximum overall resolution is a critical matter. Aperture must be decreased to improve the resolution of the outer zones, and in short-focus lenses it is decreased to the point where the outer zones produce sufficient resolution without seriously impairing that of the center. In longer focal lengths both zones improve in stopping down until the aperture approaches the size where diffraction reduces the resolution on the axis. In process-type lenses of moderate aperture, this is usually between two and three stops from the maximum

aperture. In the 24-cm Zeiss *Apotessar* $f/9$, the optimum aperture is $f/16$, and in the 19-inch Goerz *Artar* $f/11$, it is $f/22$.

In the course of this investigation of lenses another interesting observation was recorded. It was observed that with the 24-cm Zeiss *Apotessar* it was possible to produce an image on graphic film possessing a resolution of 100 lines per millimeter on the axis and 79 lines per millimeter at 15° off the axis. Photography through this same system onto a color medium of necessarily lower resolving power produced an image possessing a resolution of 40 lines per millimeter on the axis and only 32 lines per millimeter at 15° . While it might be expected that an optical system capable of producing at least 79 lines per millimeter over the whole field should produce maximum resolution all over a medium of lower resolving power, actually there is a loss in resolution between axial and outer zones on the low resolving power emulsion similar to the drop in resolution for the two zones on the high resolving material. Resolution, therefore, is not an absolute optical quantity, but is a measure of the relative degree of correction in a lens, and the analysis of resolving power data on lenses should take this factor into account.

Optical Printing.—Since the final image is to be viewed and read from a screen, negatives are not desirable, so they must be converted to positives. In the production of these positives several important observations were made. Positives have been made on three different continuous 35-mm printers, using several fine-grain microcopying positive emulsions, and in no case has the resolution of the positive been greater than two-thirds that of the negative. On the other hand, duplicate negatives made on Ozaphane in a standard Ozaphane printer show a loss in resolution of less than 10 per cent.

These observations have not as yet been fully analyzed, so no attempt is made to explain them. In fact, this part of the research is still active because considerable monochromatic microfilming of colored maps is being done for purely identification and indexing purposes. While the negatives possess sufficient resolution for these purposes, the loss of 35 to 40 per cent of this resolution in the viewing positives is a serious handicap.

Viewing Systems.—Some brief observations have been made of the effect on the resolution of the final image of different types of viewing systems. Projected images onto specific reflecting screens possess higher resolution than images projected onto translucent screens. The failure of translucent screens is occasioned by the fact that they

incorporate a diffusing medium to eliminate a hot spot in viewing. Since the projected light is the image, diffusion of the light is equivalent to diffusion of the image, or loss of resolution. Reflection viewing of projected images of maps is not desirable, so translucent viewing, such as is incorporated in the conventional microfilm reader, is used in spite of the loss of resolution which it introduces.

In connection with projection, it has been observed that the presence of granularity or grain clumping in the negative or positive has a serious effect on resolution at magnifications above which it can be resolved. At magnifications above 20x the intervening spaces between the grains act as a diffusing medium for the light, causing diffusion of the image and damaging its resolution.

Another method of viewing has been investigated in the course of this research. This is direct magnifying viewing in which the negative or positive is viewed directly with the aid of a wide-angle magnifier. This system causes the least effect on resolution because the image is viewed directly and is not required to travel through an elaborate optical system as in projection, but it offers the disadvantage of fixed magnifications. Also, suitable wide-angle magnifiers in the desired magnification range are not readily available. Such viewers would be suitable as a portable means of examining microfilm.

Color.—The reproduction of maps on color-film presents other serious difficulties. The first of these is color balance. Multilayer color-films consist of three emulsions of specific spectral sensitivities, and the color composition of the light must be adjusted so that it coincides with these sensitivities, otherwise true color rendition is not possible. Color composition is controlled by the light-source and filters, and their effect on resolution has been observed and studied.

Color temperature is a measure of color composition and correction filters are available which convert the color temperature of a specific light-source to a light of standard color temperature. Multilayer color-films are designed for good color balance with light of one of two standard color temperatures—5400°K, or daylight, and 3200°K, or Mazda. Any variations in the color temperature of the light-source will produce corresponding variations in the color temperature of the filtered light, so that for proper color rendition all the factors affecting variation of color temperature must be controlled.

Color rendition, of course, has no relation to resolution, but the use of correction filters has. In the course of this research it was observed that any obstacle introduced in the optical train of the photographic

system impairs the resolution of the image. Many types of correction filters were used—before, behind, and between the lens—and all produced this effect to a greater or lesser degree. Some filters showed as many as five fringes around each line, and even so-called “optically inert” gelatin filters produced a loss in resolution greater than 10 per cent. Correction of color temperature is best accomplished by using the filters over the light-source. While this method requires much larger filters, inexpensive types can be used because optical activity in the filters has no effect on the characteristics of the optical system.

The other difficulty encountered in the use of color-film is the low resolving power of emulsion. In monochromatic photography good

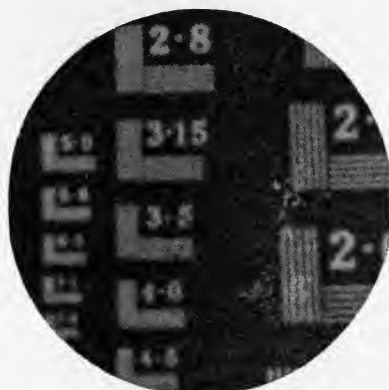


FIG. 7. 25x photomicrograph of Ansco color transparency.

resolution of image is possible because emulsions can be selected which possess resolving power greater than that of the optical system, but in multilayer color emulsions the resolution of the final image suffers, not only from the aberrations of the optical system but also from the low resolving power of the emulsions themselves.

Both Kodachrome and Ansco Color were investigated in this research, and it was found that the resolution of both standard materials under similar optical conditions was in the neighborhood of 40 lines per millimeter on the axis (Fig. 7). In view of this and of the fact that Ansco Color could be readily processed by the user, the majority of the investigations in color was conducted on this medium.

Ansco Color film is a monopack, or multilayer color process, possessing three balanced gelatino-silver-halide emulsions, each layer

of which is sensitized to record one of the tricolor components of the spectrum.⁹ The emulsion layer next to the support is red-sensitive, the middle layer is orthochromatic green-sensitive, and the top emulsion layer is color blind blue-sensitive. Each layer contains non-diffusing dye-couplers which in processing combine with the color developer to form transparent colors complementary to the color for which each emulsion layer is sensitized. Kodachrome is similar to this, except that no dye-couplers are used in the material. The individual emulsion layers are selectively dyed during processing by exposure to colored lights and development in dye-coupling developers.

The manufacture of such products is an extremely difficult process requiring delicate control and a high degree of precision. For all emulsion layers to expose together and for proper color rendition, the individual emulsions must be critically balanced for speed, contrast, and color sensitivity corresponding to a standard color temperature of either 3200°K or 5400°K.

In order to produce a final product of moderate speed, the constituent emulsions must be relatively fast. Fast emulsions are generally of low resolving power because of their grain structure. It is evident then that the superposition of three such emulsions must necessarily produce a medium of low resolution. Since no variations in exposure and processing are permissible, little can be done to correct this condition in standard commercial color emulsions where moderate speed and long-scale reproduction are desired. In map reproduction, however, slower speeds and higher contrast or shorter scale are desirable. Both Eastman Kodak and Agfa Ansco have produced experimental multilayer films specifically for this problem, consisting of slower, fine-grained individual emulsion layers, and while color rendition suffered somewhat from unbalanced contrast in the layers, resolving power was improved to produce an image with 56 lines per millimeter on the axis. Little hope is held out for further improvement of this resolution soon, because of the pressure of other important problems, and because of the difficulty of changing and balancing the emulsions composing a multilayer color-film.

CONCLUSIONS

As a result of the observations made during this research and a careful study and analysis of their results, several important conclusions can be drawn:

- (1) The reproduction of colored maps in color on a double non-

perforate 35-mm frame is impossible, because multilayer color-film materials do not possess the necessary resolving power. Reductions of 10x are possible using critical focusing and a high-resolution optical system similar to the 24-cm Zeiss *Apotessar*.

(2) The reproduction of colored maps in monochrome on a double non-perforate 35-mm frame is not satisfactory, because at minifications above 20x the phenomenon of grain clumping seriously interferes with fine line patterns, especially in areas possessing intermediate tones. It is, therefore, recommended that for continuous tone subjects the reductions be limited to 15x and for large subjects 70-mm roll film should be considered.

(3) The resolution of an image is a composite function depending on the degree of correction in the optical system producing it, the resolving power of the material reproducing it, and the processing which it undergoes. All factors that affect any of these processes will affect the resolution of the final image.

REFERENCES

¹ These targets were originally designed by the Photographic Section of the National Bureau of Standards, and a modification of this design is distributed by Agfa Ansco, Binghamton, New York.

² "Materials and Technique for Photomechanical Processes," The Gevaert Co. of America, Inc. (1939).

FORMULA GD-190

Hydrochinon (High Contrast—Long Life)

Water (about 125°F, 52°C)	2000 cc.
Potassium Metabisulfite	30 g.
Sodium Sulfite (anhydrous)	120 g.
Hydrochinon	90 g.
Sodium Carbonate (monohydrated)	240 g.
Citric Acid (crystals)	5 g.
Potassium Bromide	12 g.
Water to make	4000 cc.
Time of development: 4 to 5 minutes at 65° to 70°F (18° to 20°C).	

³ MEES, C. E. KENNETH: "The Theory of the Photographic Process," p. 901.

⁴ NEBLETTE, C. B.: "Photography, Its Principles and Practice," Fourth Edition, p. 380.

⁵ MEES, C. E. KENNETH: "The Theory of the Photographic Process," p. 85.

⁶ MEES, C. E. KENNETH: "The Theory of the Photographic Process," p. 79.

⁷ MEES, C. E. KENNETH: "The Theory of the Photographic Process," p. 865.

⁸ MEES, C. E. KENNETH: "The Theory of the Photographic Process," p. 843.

⁹ FORREST, J. L., AND WING, F. M.: "The New Agfacolor Process," *J. Soc. Mot. Pict. Eng.*, **XXIX**, 254 (1937).

SENSIBLE USE OF REFRIGERANTS UNDER THE EMERGENCY NOW CONFRONTING THE INDUSTRY

A. C. BUENSOD AND R. W. WATERFILL*

Summary.—Under Conservation Order M-28, which was amended as of September 7, 1943, the use of additional Freon (F-12) has been prohibited in comfort cooling installations and its use greatly curtailed in all but essential food and essential industrial processes. This had led to the obvious conclusion that a less critical substitute be used, which, for practical reasons, means methyl chloride.

This article emphasizes the best experience of the industry to date in the hazards involved when methyl chloride is used as the refrigerant.

The urge for substitution of Freon-12 will become increasingly greater because the prospects for a sufficient production of F-12 is not in sight for the next cooling season, according to the best authorities on the subject. The authors hope that the publicity relative to the hazards involved when methyl chloride is used will be useful and that the precautions and limitations, as outlined in the ASA safety code for refrigeration, as well as any municipal code or ordinance, are followed.

Refrigeration and air conditioning made rapid progress in the fifteen years preceding the outbreak of the present war. This progress was facilitated by many things, including public appreciation and industrial necessity, as well as research, new refrigerants standardization, and the adoption and adherence to codes and ethical standards by the better organizations within the industry. While it is impossible to avoid mistakes and disappointments, the industry generally realizes its responsibility to the public.

The general public is in no position to qualify as experts on every commodity and service it enjoys in modern life. To maintain the high standard of American living it is therefore essential that the public have confidence in the established producers of these commodities. The refrigeration and air conditioning industry has realized this since it started producing commodities and services directly affecting the public, and has evolved codes and standards to protect the public and insure its merit of such confidence. This responsibility also extends to the formulation of codes to inform and guide civil authorities, builders, owners, etc.

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The evolution of codes has been a long and difficult procedure and one that promises to continue for some time. The reasons for this are chiefly that the code must follow the development of the art itself and the many uses served.

One of the principal codes of the refrigeration industry is a Safety Code designed to protect, as far as possible, public health and property. While the benefits of refrigeration and air conditioning are varied and enormous—their value today is only partially realized—it is felt that this is no excuse for compromising with safety.

Appreciating its stake in a safe and sane development of the refrigerating industry, the American Society of Refrigerating Engineers sponsored a model Safety Code for Mechanical Refrigeration under the rules and regulations of the American Standards Association, with the hope that it would serve as an American standard. In order to insure fulfillment of the broad purposes of the Code many groups, including those especially concerned with the public interest such as Underwriters' Laboratories, Inc., National Safety Council, *etc.*, participated. The current Code approved by the ASA in 1939 represents many years' work by experts in each phase of the problem, and thus stands as a certified model for incorporation in local regulating ordinances.

While it is admitted that no code will ever be perfect, the 1939 ASA Code is somewhat rigid in its public safeguards, and the Code is abreast of the current state of the refrigeration art in all basic essentials. This is particularly true in its classification of refrigerants into groups according to the relative safety with which they may be employed. While new refrigerants may be added to these groups as developed and classified it is to be hoped that the safety standards already achieved will be maintained.

The ASA group classifications based on extensive tests of toxicity and flammability are as follows:

5.11 GROUP 1

	Chemical Formula
Carbon dioxide	CO_2
Dichlorodifluoromethane (Freon-12)	CCl_2F_2
Dichloromonofluoromethane (Freon-21)	CHCl_2F
Dichlorotetrafluoroethane (Freon-114)	$\text{C}_2\text{Cl}_2\text{F}_4$
Dichloromethane (Carrane No. 1) (Methylene chloride)	CH_2Cl_2
Trichloromonofluoromethane (Freon-11) (Carrane No. 2)	CCl_3F

5.12 GROUP 2

	Chemical Formula
Ammonia	NH_3
Dichloroethylene	$\text{C}_2\text{H}_2\text{Cl}_2$
Ethyl chloride	$\text{C}_2\text{H}_5\text{Cl}$
Methyl chloride	CH_3Cl
Methyl formate	HCOOCH_3
Sulfur dioxide	SO_2

5.13 GROUP 3

	Chemical Formula
Butane	C_4H_{10}
Ethane	C_2H_6
Isobutane	$(\text{CH}_3)_2\text{CH}$
Propane	C_3H_8

The present curtailment in the use of chlorinated fluorinated hydrocarbon refrigerants, as dictated under war activities and as shown in the Conservation Order, M-28 of the War Production Board, brings to the forefront the question of substitution of refrigerants where possible in order to alleviate the serious shortage, particularly of Freon-12.

It has already been demonstrated that through ignorance and through the pressure brought to bear by owners who have no conception of the hazards involved in substitutions some deaths have been attributed to the substitution of other refrigerants than the Freon-12 for which systems have been designed. With this in mind it is well to enumerate some of the fundamental differences in safety precautions to be observed in connection with different refrigerants. The full code should be studied carefully, however, to obtain complete details and qualifications, but the following extracts from the ASA Code illustrate the principal regulations:

Sec. 7—Public Assembly Occupancies

7.20 The maximum quantity of a Group 1 refrigerant in a Direct System used for air conditioning for human comfort shall be limited by the volume of the space to be air conditioned as shown in the table at the top of the next column. (F-12, 30 lbs per 1000 cf.)

(a) When the refrigerant containing parts of a system are located in one or more enclosed spaces, the cubical contents of the smallest enclosed space other than the machinery room shall be used to determine the permissible quantity of refrigerant in the system.

(b) When the evaporator is located in a duct system, the cubical content of the smallest enclosed space served by the duct system shall be used to determine the permissible quantity of refrigerant in the system unless the airflow to

any enclosed space served by the duct system can not be reduced below $\frac{1}{4}$ of its maximum, in which case the cubical contents of the entire space served by the duct system shall be used to determine the permissible quantity of refrigerant in the system.

7.22 A system containing more than one thousand (1000) pounds of a Group 1 refrigerant shall be of the Indirect type with all the refrigerant containing parts, excepting parts mounted outside the building, installed in a machinery room used for no other purpose and in which for Group 1 refrigerants, excepting carbon dioxide, no flame is present or apparatus to produce a flame is installed.

7.31 *Group 2 refrigerants shall not be used in a system for air conditioning for human comfort, except in an indirect Vented Closed Surface System, or in a Double Indirect Vented Open Spray System, or in an Indirect Absorptive Brine System.*

Sec. 9—Commercial Occupancies

9.12 Refrigerant piping shall not be carried through floors except as follows:

(c) In systems containing Group 1 refrigerants and used for air conditioning for human comfort, the refrigerant piping may be carried through floors provided it is enclosed in an approved, rigid and tight continuous fire-resisting flue or shaft where it passes through any intermediate space not served by the air conditioning system. The flue shall be vented to the outside or to a space served by the air conditioning system. Such systems shall conform to the requirements of paragraph 9.20.

9.20 Direct Systems containing more than twenty (20) pounds of a Group 1 refrigerant when used for air conditioning for human comfort, shall be limited by the volume of the space to be air conditioned as follows: F-12, 30 lbs per 1000 cf.

9.22 A system containing more than one thousand (1000) pounds of a Group 1 refrigerant shall be of the Indirect type with all the refrigerant containing parts, excepting parts mounted outside the building, installed in a machinery room used for no other purpose and in which for Group 1 refrigerants, excepting carbon dioxide, no flame is present or apparatus to produce a flame is installed.

9.30 *A system containing more than twenty (20) pounds of a Group 2 refrigerant shall not be used for air conditioning for human comfort unless it is of the Indirect Vented Closed Surface, Double Indirect Vented Open Spray, Indirect Absorptive Brine, or primary circuit of a Double Refrigerant type with all the refrigerant containing parts, excepting parts mounted outside the building, installed in a machinery room used for no other purpose.*

9.31 More than six hundred (600) pounds of a Group 2 refrigerant shall have all refrigerant containing parts installed in a *Class T machinery room.*

Sec. 10—Industrial Occupancies

10.10 There shall be no restriction on the quantity or kind of refrigerant used in an Industrial occupancy, except as specified in paragraph 10.20.

10.20 When the number of employees above the first floor exceeds one per one hundred (100) square feet of floor area, the requirements of Commercial occupancies shall apply unless that portion of the building containing more than one employee per one hundred (100) square feet of floor area above the first floor, together with its entrances and exits, be cut off from the rest of the building by vaportight construction with self-closing, tight-fitting doors.

The authors, both of whom were engaged in the pioneering days in the use of the new refrigerants and on many occasions sat in with municipal authorities in New York City for the purpose of assisting in the formulation of municipal codes that are practical and which safeguard life and property, thought it would be of interest to quote the present provisions governing the installation of air conditioning and refrigerating systems in the City of New York. Some of the provisions from the prevailing Municipal Code are as follows:

C19-98.0—Permissible Locations

(b) *The direct method of refrigeration shall not be used in any building, whether or not a permit is required for installation therein, outside of a refrigerating machinery room except in buildings used exclusively for ice making or for refrigerating purposes, or when such method is not carried above the first floor in business buildings, or in the business sections of business buildings provided the entire system is confined to one floor in the space occupied by a single tenant, or, in the business section of a residence building when not carried above the first floor, or in a residence building occupied by not more than two families, or in any building provided a non-irritant and non-inflammable refrigerant is used.*

(f) It shall be unlawful to install or maintain a refrigerating system employing an irritant or inflammable refrigerant in or on: (2) Dance halls, court rooms, police stations, jails, subways, theaters, or motion picture theaters.

(h) The use of methyl or ethyl chloride, sulfur dioxide, or a hydrocarbon refrigerant will not be permitted in Class A systems.

C19-96.0—Permits

(c) It shall be unlawful to maintain or operate any refrigerating system employing a refrigerant other than those specified in this article without a permit issued upon such conditions, consistent with the provisions of this article, as are deemed by the fire commissioner necessary in the interest of public safety.

Note: The Fire Chief and Commissioner prescribed under date of April 4, 1934, the following:

(1) That the refrigerants. . .F-12. . .F-114. . .and. . .F-11 are *non-flammable and non-irritant*, unless otherwise hereinafter provided, and shall be regulated in accordance with the provisions of Article 18 of Chapter 19 of the Administrative Code, as such, except, when used in a room or rooms in which there is an open flame or apparatus to produce an open flame, when the provisions of said article covering irritant refrigerants shall apply.

(2) That refrigerating systems employing F-11, F-12, or F-114 are restricted to parts of a building so specified in Section C19-98.0 (b) *for refrigerants other than non-irritant and non-flammable.*

(3) That refrigerating systems employing F-11, F-12 or F-114, used for air conditioning are restricted to the indirect method except that the direct method may be used in parts of a building so specified in Section C19-98.0 (b) *for refrigerants other than non-irritant and non-flammable.*

(7) That a refrigerating system employing F-11, F-12 or F-114 shall not be installed or maintained in a theater and/or motion picture theater unless the en-

tire system is confined in a fireproof machinery room, used for no other purpose, and in which no open flame and/or apparatus to produce such open flame shall be employed, except that Class C systems containing not more than ten pounds of refrigerant may be installed in a rest room, smoking room, or lounging room provided in such rooms no open flame or apparatus to produce such open flame shall be employed.

C19-97.0—Classifications (System)

(a) The total amount of refrigerant common to a system operating through one or more evaporators, shall be considered the capacity of the system and determine its class.

(b) A Class A system is a system containing one thousand (1000) pounds or over of refrigerant, or capable of thirty (30) tons capacity or over.

(c) A Class B system is a system capable of less than thirty (30) tons capacity, or containing less than one thousand (1000) pounds of refrigerant and more than amounts provided for in a Class C system.

(d) A Class C system is a system containing not more than twenty (20) pounds of refrigerant.

With the present urge of owners to have their refrigerating systems operate, especially for comfort cooling even though Freon-12 is not available under the present War Production Board restrictions, some suggestions have been made that substitutes be used. The authors feel that all who are engaged in the servicing and in the supplying of these substitute refrigerants should carefully understand the hazards involved both in equipment and in the use of such substitute refrigerants for particular locations. We feel it would be much better to advise the owner of a comfort cooling system, especially in a theater or a place of public assemblage, that unless he can obtain a safe refrigerant as now permitted in the ASA Code (and, of course, if permitted under the Municipal Code in effect), and that unless all the precautions in these codes can be adhered to strictly, he would be better off without any refrigerating effect and to depend on his ventilation by circulating outdoor air.

It is unquestionably true, we believe, and we have so been advised by attorneys, that if anyone knowingly substitutes a refrigerant with a known hazard and life is imperiled or lost, all those performing the operation are criminally liable.

FILM CONSERVATION METHODS

A SYMPOSIUM*

The conservation of materials is one of the major objectives of all industry in this war. Particularly is this true in the motion picture industry, where the enormous requirements of the armed forces added to the essential civilian demand are creating an unprecedented consumption of photographic film. A record of the steps being taken by the various studios to insure the conservation of raw film stock during sound takes is thus of particular interest at this time.

The following eight papers make up a symposium to which representatives of the Sound Departments of as many studios in Hollywood contributed their various methods of saving sound-film by marking, removing, and reassembling non-print sound takes. The undeveloped film thus reclaimed has been exposed only along one edge and the unexposed areas may be used for a number of purposes.

This preselection practice, which constitutes a considerable saving in film raw stock and laboratory processing has been in operation for some time; however, the technique varies from studio to studio and the following papers give detailed accounts of the methods in use at each studio. The authors contributing to the symposium, in the order in which their papers appear, are as follows:

"Film Conservation Methods at Universal Studios," by George J. DeMoss, Sound Dept., Universal Pictures Co., Inc., Universal City, Calif.

"Film Conservation Methods at Republic Studios," by D. J. Bloomberg and J. Stransky, Sound Dept., Republic Pictures Corp., Hollywood.

"Film Conservation Methods at RKO Studios," by P. E. Brigandi, Sound Dept., RKO Radio Pictures, Inc., Hollywood.

"Film Conservation Methods at Columbia Studios," by S. J. Twining, Sound Dept., Columbia Pictures Corp., Hollywood.

"Film Conservation Methods at Paramount Studios," by I. M. Chambers, Sound Dept., Paramount Pictures, Inc., Hollywood.

* Presented before the Pacific Coast Section meeting, Hollywood, May 25, 1943.

"Film Conservation Methods at Samuel Goldwyn Studios," by D. A. Newell, Sound Dept., Samuel Goldwyn, Inc., Hollywood.

"Film Conservation Methods at Walt Disney Productions," by C. O. Slyfield, Sound Dept., Walt Disney Productions, Burbank, Calif.

"Film Conservation Methods at Warner Bros. Studios," by G. M. Best, Sound Dept., Warner Bros. Pictures, Inc., Burbank, Calif.

FILM CONSERVATION METHODS AT UNIVERSAL STUDIOS*

GEORGE J. DEMOSS**

To date our sound breakdown system involves utilizing all non-print takes and short ends salvaged from Daily production, dubbing, music and sound-effects recording. The non-print takes are segregated as to companies and held pending verification of production release from the Exchange Office. Inasmuch as the opposite edge is not exposed during recording, this film is made available for print stock. The print takes are then assembled and sent to the laboratory for Daily processing.

Short ends accumulated from all negative recording are spliced together in approximately 990-ft lengths and re-used as negative recording stock for music production, playbacks on musical productions, silent sound-track for negative cutting, or as direct leader stock.

In the past the procedure has been to open the recorder door after each take to identify the scene number by marking through the center of the film with a soft lead pencil. At this point of operation the film is also edge-notched with a hand punch to facilitate the breakdown in the Camera Department. Owing to fogging the opposite edge of the film and to the allowance made for splicing losses, the above manual operation results in the loss of three feet of otherwise available printing stock each time the recorder door is opened between scenes.

Identification for actual breakdown of the exposed film in the camera department depends on the sound log, camera card, the footage, and the edge notch. After segregating the print takes from the non-print takes it is necessary to remove edge notches, double scrape, and tape the film so it will survive all mechanical phases of laboratory processing, such as developing machines, printing machines, *etc.*

* Presented before the Pacific Coast Section meeting, Hollywood, May 25, 1943.

** Sound Department, Universal Pictures Co., Inc., Universal City, Calif.

To identify the positive print scene number for cutting purposes the negative slate, as it appears written on the picture area of the film, must be transferred to the sound-track area by inking in or by the use of a stylus in the laboratory. This procedure is necessary because all sound printing at present involves the use of a matt which only allows exposure on the actual width of the negative sound-track.

With the photographic sound slater now in use it is not necessary to open the recorder door as the scene numbers are predetermined by the progressive slate number system and are exposed and center-punched by electrical apparatus. This saves considerable time and also three feet of film between each two scenes or takes which would otherwise be fogged.

Film breakdown in the Camera Department is facilitated as the photographic sound slater eliminates all edge notches by center-punching the film on the recorder. Inasmuch as the exposed slate number is not visible until after negative development, the practice of stopping at each edge notch to visually identify the scene number under darkroom conditions, and especially the legibility of slates written in by hand, is now supplemented by the use of a footage indicator in conjunction with the dial footage log of the sound card.

The use of this new breakdown technique in the Camera Department and the elimination of all edge notching reduce the time previously consumed in splicing, taping, and all predevelopment physical handling of the film.

In the laboratory it is no longer necessary to identify the legibility of, or to transfer written slates, as the scene numbers are now exposed directly in the negative sound-track area. This avoids the use of India ink, faulty scratching in of slates by hand, and assures legible, permanent scene numbers.

Table I reveals that a total of 1,229,000 ft of non-print takes and short ends became available for re-use during 1942. Also there was a laboratory processing saving on 1,809,372 ft.

TABLE I

	Feet
Negative purchased (all companies).....	6,401,375
Print negative developed.....	4,592,003
Savings on laboratory processing of non-print takes.....	1,809,372

Salvage of Short Ends

	Feet
(1) Used as music protection*.....	9,000
(2) Playback negative and leader stock sales.....	100,000
(3) Sound-effects and silent sound-track negative.....	76,000
(4) Direct to leader stock.....	11,000
(5) Used at the laboratory for printing stock (library numbers)...	13,000
	<hr/>
Total.....	209,000

Salvage of Non-Print Takes

(1) Used as music protection negative to leader stock*.....	66,000
(2) Used by the laboratory for printing sound Dailies.....	954,000
	<hr/>
Total.....	1,020,000

* Used as negative plus subsequent use as leader.

FILM CONSERVATION METHODS AT REPUBLIC STUDIOS*

D. J. BLOOMBERG AND J. STRANSKY**

Previous to 1937 it was customary to record full-length reels of dubbing on only one side of the film. In 1937 the procedure of using both sides of the sound negative was adopted. This two-sided recording is done only if the previous take on one side of the reel is a non-print take. Unless the recordist gets an immediate print order on a take he runs the recorder for an additional 25 feet at the end of the take. The short end is saved and the 25 ft allowance is enough to rethread the machine and get up to speed. The first take is not spoiled by this process and may be used up until the time the standard leaders are cut on. This practice has resulted in no difficulties in the studio or at the laboratory. The saving for one year's production is approximately 150,000 feet.

Our next economy was the process of re-using all non-print sound takes, both from production and scoring. Our slating devices on the recorders incorporated a film punch which punches a hole in the center of the sound negative at the same time a scene number is photographed in the sound-track area. This punch hole, and the scene footages, enabled the breakdown man to remove only the print takes from each roll, splice them together, and send them to the laboratory for developing and printing. By using photographic slates the recording door is never opened for a full 1000-ft roll. The film movement is viewed through a red filter in the recorder door and a red light is directed behind the film loops.

All the breakdown splices are made with a standard Bell & Howell negative machine. These splices are taped over with a piece of waterproof tape for strengthening and greater protection. In four and one-half years' operation there has not been a single breakage of a splice.

A flashlight properly filtered is used to read the sound report when breaking down sound negative.

* Presented before the Pacific Coast Section meeting, Hollywood, May 25, 1943.

** Sound Department, Republic Pictures Corp., Hollywood.

All film is run through a footage counter set to read in reverse because of the fact that the rolls are tails out. The film is rolled up on two take-up reels, one for the print takes and one for the non-print takes. This leaves the non-print takes on 1000-ft rolls.

A system of marking the non-print takes is used to make it possible to find them without difficulty.

Immediately after the picture has been released these non-print takes are used to print Daily sound and sound-effects tracks.

Owing to the fact that Class B push-pull sound is used, there is no trouble caused by the breakdown splices in the printing stock.

This breakdown process has other advantages besides film economy. An approximate reduction of 50 per cent in laboratory expenses and chemicals is accomplished and a noticeable reduction in film handling marks. Results show an average saving of 130,000 feet of film per month.

In February, 1942, a film punch adapter was put into use on all action cameras, and the same process of breakdown has been used. The breakdown room is dark except for a shadow box for the film reports. The darkened room presents no difficulty to an operator familiar with the breakdown apparatus and procedure. The numbers on the footage counter are painted with luminous paint.

The non-print takes are used by both the Editorial and Sound-Effects Departments for leaders. Extensive tests were made using the picture non-print takes as a sound negative and acceptable results were obtained; however, this is not being done at present. Using action* non-print takes as leader stock saves buying approximately 75,000 feet of leader stock per month.

In 1940 an automatic starting device was installed on all the sound trucks. Its purpose is to light the red lights, ring the "quiet" bell, start the recorder and camera, expose "sync" marks on picture and track, put an exposure density on the sound negative, and give a "speed" signal on the set. At the end of the take the recording machine and camera are stopped, the red light is turned off, and the "quiet" bell rings twice. By using this device the timing of each of these operations is adjusted to use as little film as possible consistent with good operation. It is estimated that at least two feet of both sound and action are saved on every take. The starting device can be operated from the stage or the sound-track.

* Picture, not sound-track.

In 1942 split film (17.5 millimeters) was adopted for all sound-effects, music, and dubbing prints used in re-recording. The change necessitated building a film splitting device with a tolerance of ± 1 mil and converting all re-recording reproducers, sound-effects, and music moviolas to operate with 17.5-mm track. Two re-recording reproducers were arranged to run either 35- or 17.5-mm track to make them available for use with 35-mm sound-track which is still used in the Editorial Department and for playback tracks and composites. The annual film saving is approximately 805,000 feet, and the cost of altering the machines was approximately \$5000.

About two years ago, the policy of obtaining an extra print for playback in case one is damaged was abandoned. All vocals are recorded on two channels and then temporarily dubbed together for a playback track and for cutting purposes. Only one print of this is made but the negative is used as a standby print for the playback operators. The print is given to the Editorial Department in the evening of the day it is finished as a playback track. The print is then used as a work-print by the Editorial Department for cutting purposes. With this procedure no film is saved by using an acetate disk for playback. Savings are about 19,000 feet per year.

When playbacks are used on production the master playback scene is recorded full-length for synchronizing purposes. The remaining angles are recorded for the first fifteen feet only. These recorded tracks are then developed only and the negative is used to synchronize the playback with the picture. The saving is approximately 60,000 feet per year.

In April, 1942, re-recording directly from the sound work track was started and has been continued on all Serials, Westerns, and low budget pictures. Using the work track as a dubbing print has given no trouble in obtaining a re-recorded negative that compares very favorably with pictures recorded from a new negative film and with new dubbing prints. This again was made possible by Class B push-pull recording, because of the fact that it is so easy to bloop out splices, scratches, *etc.* The saving for one year was 364,000 feet.

In the Camera Department all ends over 75 feet are saved and used in shooting inserts. This presents no material difficulty in shooting inserts owing to the fact that scenes are usually very short

and no valuable time is lost by loading. This resulted in approximately 24,000 feet of film saved last year.

All sound short ends over 15 feet long are saved. They are spliced into 1000-ft rolls of the same emulsion and used to print sound-effects. The effects are printed on each edge and then the film is split. The saving for 1942 was approximately 150,000 feet of full-width film.

In June, 1942, a large surplus of non-print sound takes was found, and it was decided after numerous tests to use this film as production sound negative on the low budget productions. This was made possible again by the use of Class B push-pull which cancels out nearly all noise from the splices. From June 16, 1942, to January 25, 1943, when the supply returned to normal, 428,635 feet of sound negative had been saved.

Early in 1941 production leaders at the head and tail ends of exposed rolls of action negative and sound negative were reduced from fifteen to five feet. This resulted in a film saving for 1942 of 135,360 feet.

The Sound-Effects Department has adopted the policy of re-using sound-effects that have previously been assembled without cutting them from the stock library reel. This usually necessitates using sound-effects tracks which are much longer than the pictorial scene in order not to cut the print. While this technique has presented no problem in dubbing, and the policy has saved a good deal of film in prints, it has cost more in cutting labor.

As many stock shots as possible are used, particularly in westerns and serials where the same characters, or poses of a number of men for chases, run-bys, *etc.*, appear. Wherever practical, dialog in the script is simplified so that performers do not have trouble in memorizing and pronouncing.

As far as practical only that part of master scenes which is to be used in pictures is photographed. All rehearsals on film are eliminated and wherever possible only one take is printed.

Trailer lengths have been reduced to 100 and 150 feet.

Reprints of Dailies are not ordered unless unusable for projection, and these average less than ten a month. We use only one picture and sound print for all departments.

No dissolves or fades or montages are ordered until the picture has been cut. These are all marked with red pencil during the cutting

process. Fine grains for fades, lap, and dissolves are ordered for only five feet each side of the effect.

Trailer tracks and fine grains are ordered from footage to footage.

Only two background process prints are ordered instead of three or four as was done previously. These prints are left in the Process Department and used over and over again. All tests are shot with spliced action, or if possible, stills are used.

FILM CONSERVATION METHODS AT RKO STUDIOS*

P. E. BRIGANDI**

RKO Studios have been using the preselection or breakdown system to conserve film and reduce operating costs since its first use in Hollywood. This general procedure has been of considerable saving to the studio.

However, the amount of stock available for printing purposes was not sufficient to print all of the sound Dailies at RKO Studios until the photographic slating device and center punch were added to the recording machines. Since that time the stock recovery has been increased by more than fifty per cent. This has resulted in much greater savings as the amount of stock now available is more than sufficient to print all sound Dailies. The surplus is used in numerous ways that will be mentioned later.

The general method used in breakdown is to separate the non-print takes from the print takes. The non-print takes are then put into cans and held until the picture has been released. At this time they are assembled in 1000-ft rolls for printing purposes. To insure that this stock is free from fog, handling marks, and abrasions, a number of changes in equipment have been made, as follows:

(1) Safelight windows with protecting covers were installed in the recording machine door, permitting the operator to watch the loop and check the film travel in the machine without opening the door and fogging the film.

(2) All of the rollers, magazine, recording machine, and rewind were undercut and proper clearances provided to prevent damage to the film on the side opposite the normal negative track position.

(3) Marks on the film from handling were reduced by training the breakdown personnel to hold the film by the edges as they applied pressure while rewinding to locate the center punch identifying each scene.

(4) A splicing machine with footage counter and weighted rewinds was installed in the breakdown room to prevent cinch marks and abrasions and yet provide for rapid repair of the rolls.

* Presented before the Pacific Coast Section meeting, Hollywood, May 25, 1943.

** Sound Department, RKO Radio Pictures, Inc., Hollywood.

The principal use made of the sound-track negative recovered by preselection is in printing sound Dailies. The next largest use made of such film is in printing of composite dupe-negatives and prints after editing is completed on a picture. These are made from the work-track and action, and are used by the music and cutting departments, *etc.*, in preparing for re-recording. Some other uses are noted, however; as individual items they constitute a small part of the total film recovered:

- (1) Leader stock (the majority of this is obtained from small rolls that are not spliced together under a safelight).
- (2) Action prints for the trailer department.
- (3) Unmodulated track prints.
- (4) Sound reprints.
- (5) Sound and action stock shot prints for inspection purposes.
- (6) Film to be used in cameras or recording machines for various mechanical checks.
- (7) Negative sound-recording stock for production cue tracks. (These are not printed, but after development are turned over and used as positive. This procedure is also used with cue tracks or playback tracks shot on good negative. In either case, the recording machine shutter is set to clear the track area.)

Also, it was planned to use the reclaimed stock for picture Daily prints. To make this possible, the sound department equipped the recording machines to handle fine-grain release positive stock as a sound-recording negative, the film being supplied by the manufacturer with negative spools and edge numbers. This was done about two years ago, but with the conservation program that has been in effect since the start of the war, the number of non-print takes made by the production companies has decreased to a point where the recovery of stock is not sufficient to provide enough for the action Dailies.

The action negative at the present time is not preselected, but a great saving has resulted in the elimination of the majority of short ends. The general practice is to reload the camera only if the remaining short end is less than sixty feet.

FILM CONSERVATION METHODS AT COLUMBIA STUDIOS*

S. J. TWINING**

Preselection as a means of film conservation, although important in itself, can not be discussed without going into the broader aspects of the general economy of operation. Even where the saving of film is of prime importance, as it is at the present time, the details of operation are bound to be modified by other existing circumstances.

Those groups which operate their own laboratory as an integral part of the studio must keep in mind the combined picture of simultaneous economies resulting in Camera, Sound, and Laboratory Departments, since the operations of these departments are interdependent and economies arbitrarily established in one department without due regard to the effect on the others may result in non-compensated losses.

On the other hand, studios which have their processing done in a commercial laboratory have only their own particular economies to consider and individually the Camera and Sound Departments may be able to effect greater economies than would be possible were they required to fit into the larger picture.

In the case of Columbia Studio, film conservation methods must through necessity be fitted into a larger plan of general economy since Columbia operates its own laboratory, covering the complete field of negatives, daily prints and release printing. Keeping these requirements in view, we can now proceed with a description of our present methods of operation and the reasons therefor.

We will consider first the sound negative. The procedure is as follows:

As the roll of film passes through the recording machine each take is manually marked with its proper scene number. A hole is punched

* Presented before the Pacific Coast Section meeting, Hollywood, May 25, 1943.

** Sound Department, Columbia Pictures Corp., Hollywood.

in the center of the film to serve as the synchronizing mark and two holes are punched to indicate the end of the outgoing scene. The double punch mark indicates that the film may be broken at this point without loss of the synchronizing mark or damage to the take.

The Recorder keeps two sets of records: one, the usual Recording Report for use of the Laboratory, Editorial, and Sound Departments, and the other, a report for the Sound Loading Room on which are listed only the take numbers and corresponding footages, with printed takes circled. This report is made in large-sized figures with heavy pencil since it is to be used in the safelight of the loading room.

All film loading is carried out in a room centrally located and sufficient personnel is provided so that the preselection breakdown can also be carried out at this point. Exposed film is taken out of the magazines and placed on flanged rewinds operated in connection with a film footage counter and a stapling machine. The breakdown man has before him the large figured report and as he rewinds the negative from tail to head through the counter, which gives him a check on footage, he cuts out the print takes* noted on the report and places them in one stack. Those sections which are composed of non-print** takes are placed aside in another stack.

The print takes are then progressively taken up on the rewind flange and stapled together at the ends to form a continuous roll of approximately one thousand feet, which is sent to the laboratory for development and subsequent printing. The rolls of non-print takes are taped at the ends and each roll is marked on the tape with the included take numbers. These non-print rolls are then grouped in cans, appropriately labeled and placed in temporary storage.

If for any reason prints should be needed at a later date on takes which were originally designated as non-print, an order is placed with the Sound Department listing the take numbers required. The exposed negative is readily located in the temporary storage group of non-print takes, is taken out, and sent to the laboratory for inclusion in the next negative developing run.

Non-print negatives are held in the temporary storage until each

* Also termed, "O.K." takes or selected takes.

** Also termed, "N.G." takes or out-takes.

particular production has received its final editing at which time they are released for conversion to other purposes.

For a period in the past it had been our practice to carefully resplice this stock in the darkroom and turn it over to the laboratory for the purpose of making Daily sound prints. This operation presented some difficulties from time to time.

If the stock which was being currently used for sound negative was similar in characteristics to that used in the laboratory for release printing, the sound quality return generally remained on a satisfactory basis. But if the characteristics of the sound stock differed materially from that being used in releases, difficulties occurred. Prints made on converted stock when run at release developing time resulted in unsatisfactory gamma characteristics. To correct this condition it was necessary for the laboratory to change developing time during the release runs, which resulted in lost production time for the developing machines.

As a consequence this procedure was eventually abandoned and a better one substituted. Our present method is to make all Daily prints, both sound and picture, on spliced stock supplied by the laboratory from short ends resulting from release printing. This stock, being from the current release emulsions, returns optimum quality at all times and can be run through the developing machines without the necessity of changing developing time.

Non-print sound negative stock is now economically converted to a number of useful purposes. When rewound so that the opposite edge can be used for recording purposes, it is employed in making test runs of sound equipment, toe recorded negatives for synchronous playback, and sound and music-effect negatives. A considerable amount is sent to the laboratory and converted into clear leader which is used by the Foreign Department in their superimposed title work. Additional amounts are supplied to the Sound Effects and Editorial Departments for use as opaque leader. At times some of this stock is sold to outside customers for the purpose of making sound negatives or prints.

The foregoing remarks on preselection and the conversion of residual stock have pertained to negative which is used in connection with production recording. A different type of preselection, if it may be referred to by that term, is applied to the dubbing operations. Here we have residual stock which is in continuous 1000-ft lengths representing unsuccessful or non-print dubbing takes. As

in the previous case, only that negative which has been designated for print is sent to the laboratory for development. The non-print takes are rewound so that the opposite edge is presented for recording and are again used for temporary negatives in connection with recorded playbacks, when the occasion requires, and for separate track previews.

In the case of picture negative a different procedure is followed. Several years ago a limited method of preselection was employed in the handling of this negative in which only those rolls which contained print takes were sent through the developing processes, resulting in some economy under the conditions which obtained at that time. As the speed of the negative emulsions was increased, it was found that when rolls were developed which had been in storage for a period of perhaps a month or two, such negatives carried a very bad haze that destroyed their usefulness. It is possible that this condition could have been improved by a more elaborate system of storage involving a dependable system of air conditioning with some overall economy.

Inasmuch as Columbia Studios operates its own laboratory it has been considered that the economies which might be effected by a system of preselection of picture negative in the developing operation would be more than offset by the cost of operation of a breaking-down system and the attendant risks in handling the negative for the additional operation. It seems obvious that in the case where the negative is developed by a commercial laboratory on a cost per foot basis, money could be saved by a well worked out system of preselection. Economy of film utilization, however, does not seem to be indicated in this case since the picture negative, once exposed, has been entirely expended and does not have an opposite edge as in the case of sound negative which can be used for another recording.

The term "preselection" does not strictly apply to those operations which are primarily a laboratory function, but it might not be amiss to mention here a laboratory operation that has resulted in some economies in film and considerable more in time. This operation might be termed "presynchronization of the Daily picture and sound." It had been our practice in the past to bring Daily picture and sound print out of the laboratory as independent assemblies after which the two sets of prints were assembled take

by take for review. This print synchronizing operation resulted at times in quite an appreciable film wastage and considerable delay.

The two negatives are now synchronized before printing at which time all surplus beginnings and ends of takes are trimmed off and negative groups are assembled of full reel size. When the two prints come out of the laboratory developing operations they are immediately available for synchronized review.

FILM CONSERVATION METHODS AT PARAMOUNT STUDIOS*

I. M. CHAMBERS**

This paper describes our film conservation methods as applied to sound-film only. We use one edge of the 35-mm film for the original track, and save all undeveloped takes until the picture is released. The opposite edge of this film is then used for other sound negatives or prints as required.

This subject is divided into (a) methods of conserving the stock, such as prevention of fog, identification of takes, separation of print takes and non-print takes, and (b) release of non-print takes for second choice prints and the final release of non-print takes for re-use.

Prevention of Fog.—The first requirement is that the edge of the film opposite the original sound-track must not be fogged. This is accomplished in the recording machine by a shutter mechanism controlled by the motor system to prevent exposure when the machine is at rest, or by a relay system controlled by the motor system to drop the lamp filament to a very low temperature during the rest period. It is important that excess daylight be prevented from entering the lens system if the latter method is used. Darkroom fog is not generally too serious, but if considerable time is used to make the splices it should not be ignored.

Identification of Takes.—The identification of takes is accomplished by the recording operator keeping a very accurate log of the footage of takes and faithfully punching the film at the start of each take. Fog sections incurred during reload, bias, motor, or light valve checks, are identified by having the recording operator roll three feet of film by hand, with a punch mark before and after each operation. These fogged sections are removed in the darkroom during the breakdown procedure.

* Presented before the Pacific Coast Section meeting, Hollywood, May 25, 1943.

** Sound Department, Paramount Pictures, Inc., Hollywood.

Separation of Print Takes and Non-Print Takes.—The next operation is the breakdown or separation of print and non-print takes in the darkroom. In order to simplify the breakdown the film is first completely rewound on a motor rewind and appears heads out. This roll is placed on the left-hand rewind, as shown in Fig. 1, and threaded through the counter, emulsion up, and the counter set to zero at the first punch mark.

All print takes are spliced and reinforced with splicing tape, two inches long by three-quarters of an inch wide, on the celluloid side

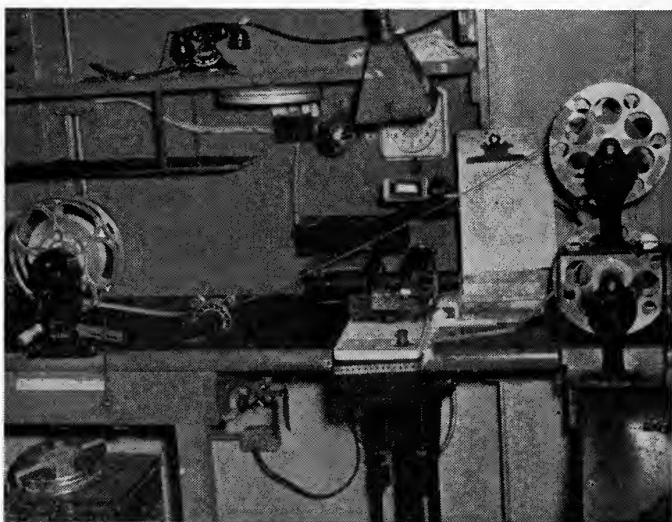


FIG. 1. Section of the darkroom showing breakdown equipment.

only and wound on the lower reel of the right-hand rewind which is equipped with a positive spool. Each scene and take number is marked on the film in pencil twelve inches in from the punch mark. Productions are not mixed and all print takes of a production are wound on one spool until approximately 950 feet is obtained, or until the production is finished for the day. Each roll is marked with the production number and the first and last scenes, and a 15-inch leader is spliced on the end before being sent to the laboratory for development.

All non-print takes are wound on the upper rewind, equipped with a negative spool, and are not spliced but held together only with

splicing tape. If several non-print takes appear together, only the first scene and take are marked with pencil for identification. This process is continued until approximately 950 feet are accumulated on a roll before another one is started.

Release of Non-Print Takes for Second-Choice Prints.—Release of non-print takes for second-choice prints is facilitated by storing all non-print takes in cans with the production number and the first and last scene numbers marked on the can. In addition, each can is numbered and every log sheet used in the breakdown of the film in

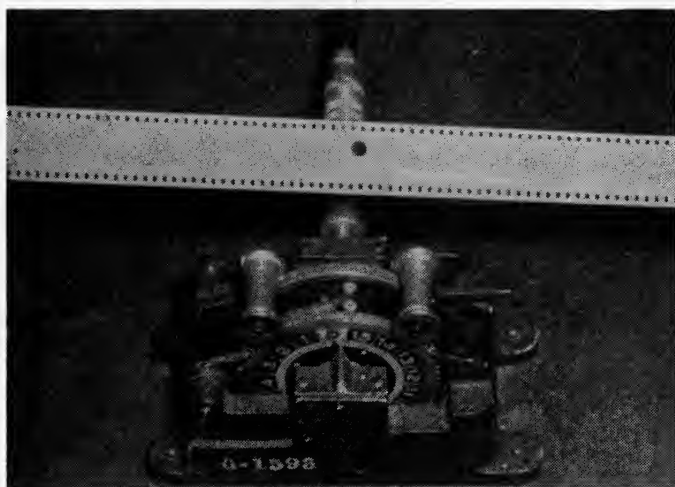


FIG. 2. Footage counter equipped with air jets to locate punched holes.

this can is marked with the same number. If the Cutting Department requests a print of a non-print take it is a simple matter to locate the take number and the can number from the log sheets, and also the location of the take in the can.

Final Release of Non-Print Takes.—All non-print takes are kept until a release is issued by the Production Department. This is usually some time after the picture is released in the theater.

Before describing the uses of non-print stock I would like to review several practical ideas purposely left out so as not to disturb the continuity of the process.

Finding the punch mark by eye has always been a slow process even though the footage is known. This difficulty has been elimi-

nated by forcing a stream of filtered air through a jet against the film with just enough pressure to produce a hissing sound. When a punched hole is encountered, the character of the sound is changed completely for an instant even though the film is traveling at a fairly high rate of speed. One jet is used when the roll is heads out and the other when tails out as shown in Fig. 2.

It is not necessary or desirable for the air to flow continuously but only as a punch mark is approaching. The air is controlled by a valve, shown in Fig. 3, operated by the left knee of the break-

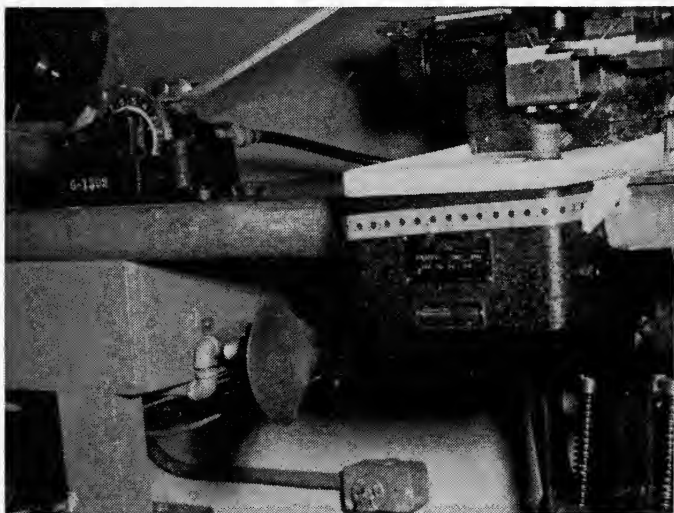


FIG. 3. Knee-operated valve controlling air to jets in footage counter.

down man when his footage counter indicates to him that the beginning of the next take is near.

Splice breakage in the negative developer is costly and has been eliminated by timing each splicing operation to 15 seconds. An electronic timer controlled by the top right-hand section of the splicing machine lights a small bull's-eye at the beginning of the splice and the light is automatically extinguished in 15 seconds—thus eliminating possible mistakes in timing by the operator.

Splices are made in the normal manner except that cement is not applied to the scraped section but is applied to the celluloid side of the film that contacts this scraped section. This is done because

the base of the splicing machine is heated and the cement dries too rapidly if applied in the normal manner.

After release all non-print takes, that is, all takes exposed on one edge only, are spliced together without reinforcing tape into three groups, as shown in Table I.

TABLE I

AVAILABLE STOCKS AND USES

(A) *Sound-Track Exposed on One Side*

	Size of Roll
(1) Over 500 ft.....	Over 500 ft
(2) Between 200 and 500 ft.....	1000 ft
(3) Between 20 and 200 ft.....	1000 ft

(B) *Unexposed Stock*

(1) Over 500 ft.....	Over 500 ft
(2) Between 20 and 500 ft.....	1000 ft

(C) *Miscellaneous Stock*

- | | |
|-------------------------------------|-----------------------|
| (1) Stock not included in the above | |
| (2) Non-fine-grain stock..... | Spliced to any length |
| (3) Variable-area stock..... | Spliced to any length |

(A) *Sound-Track Exposed on One Side.*—(1) Sections over 500 feet obtained largely from dubbing negatives are used (a) for prints and reprints of sound-effects for the Film Library, (b) for prints and reprints of mike pick-up takes (a mike pick-up take at this Studio refers to sound or dialog recorded at the Studio to match picture that was made silent), and (c) for dupe prints as needed on Technicolor pictures for dubbing, scoring, etc. (2) Sections between 200 and 500 feet obtained both from dubbing and Daily production negative are used only for dubbing daily prints. (3) Sections between 20 and 200 feet obtained largely from Daily production negative are used (a) for production Daily prints and reprints, (b) for prints on all cue tracks for production, (c) for the first dubbing print of a cut negative (this is a work print only and is not used for final dubbing), and (d) undeveloped as silent sound-track for dubbing and editing purposes.

(B) *Unexposed Stock.*—(1) Sections over 500 feet exist at present only when a complete change of emulsion is made on all recording machines and several thousand feet of original stock are left. Its uses are (a) production temporary recording or throw-away track, (b) tem-

porary dubbing negatives, (c) temporary mike pick-up negatives, and (d) production tests.

If insufficient unexposed stock is available then these uses are transferred to (A-1) above. (2) Sections between 20 and 500 feet usually cover stock between 20 and 100 feet because all medium length short ends are used on production. This stock is sent to the laboratory to be used as black leader for picture cutting, for printing leaders, and for other print uses such as fade-ins, fade-outs, dissolves, etc.

(C) *Miscellaneous Stock*.—This includes (1) all short ends not used above, (2) non-fine-grained low gamma negative stock used for white light printing, and (3) short ends of negative stock used on ultraviolet variable-area recordings. These stocks are all grouped together and sent undeveloped to the Editorial Department to be used as silent sound-track in their work-prints and are not to be used for dubbing.

FILM CONSERVATION METHODS AT SAMUEL GOLDWYN STUDIOS*

D. A. NEWELL**

Conservation of sound-track film at Samuel Goldwyn Studios operates as follows:

Each roll of film as it is threaded on the recording machine is given a magazine card. On this card appears the production number, date, machine number, emulsion, magazine number or numbers, and the operator's name. This card has three columns in which are written the track number, the accumulated footage, and the take footage. Enough room is also provided for remarks pertaining to this particular roll of film—such as missed punches and slates or special laboratory handling. Special laboratory handling may include such items as two or more prints on a certain track, a change in gamma of either negative or print, or a develop-only order.

An externally operated punch is located at one end of the recorder just before the film passes into the exposed side of the magazine. This punch cuts a $\frac{5}{16}$ -inch hole in the film approximately $\frac{1}{16}$ inch from the sprocket-hole. Some care had to be taken with the design of this punch in order to keep the punchings away from the exposed portion of the film. The plunger is light sealed and altogether is quite a simple set-up. Each take is, of course, punched at the beginning.

The slating device carries four rows of movable figures. In addition to nought to nine there are also provided prefixes for scoring, dubbing, sound-effects, "wild" lines, and tests. This device is also externally mounted and operated thus allowing the entire roll of film to be run through the machine without fogging. A starting mark is fogged on the film by momentarily opening the lamp shutter while the slate is being photographed. Provision is also made in the slating set-up to include the production number and also whether or not the track is preëqualized.

* Presented before the Pacific Coast Section meeting, Hollywood, May 25, 1934.

** Sound Department, Samuel Goldwyn, Inc. Hollywood.

After each roll of film is exposed the magazine file card is placed in its holder and taken to the breakdown room. The film is then broken down. The safety lights in this room are equipped with *OA* series filters and 10-watt lamps delivering a relatively bright light which, with ordinary recording stock, has been found to be safe during handling time. Each take is properly identified and wrapped in black lightproof paper and placed in ordinary film cans which are stored in consecutive order for possible later processing.

Approximately sixty days after release of the picture the unwanted non-print takes are assembled into 1000-ft rolls and used for printing Dailies. In assembling these rolls the longer scoring, dubbing, and Daily takes are used and the shorter takes are set aside for leader and dubbing fill-in stock.

This system has been in operation for over ten years and has saved noticeably in two instances—first, in the cost of negative development and, secondly, in the partial cost of print stock. Table I illustrates savings on four typical pictures.

TABLE I

Production No.	Negative Exposed <i>Feet</i>	Negative Developed <i>Feet</i>	To Laboratory for Re-use in Printing <i>Feet</i>
(5900)	208,000	137,000	30,000
(108)	1,107,000	538,000	182,000
(4500)	235,000	122,000	102,000
(5600)	443,000	255,000	102,000

We found that owing to variation in transmission care must be taken to keep the same emulsion together for print stock. Also the splicing machine requires more frequent attention in order to minimize laboratory trouble from broken patches.

FILM CONSERVATION METHODS AT WALT DISNEY PRODUCTIONS*

C. O. SLYFIELD**

About 1933, it was decided in the Sound Department of Walt Disney Studios that some procedure should be established whereby only "selected" takes would be sent to the laboratory for processing. With this in mind, the following system was adopted:

At the time of recording, the take numbers are punched in the film and a notch, similar to a timing notch, is punched on the edge of the film to assist the film breakdown man in locating the take number. After recording, the film is taken into the darkroom and broken down into "selected" and "hold" takes under a safelight. On each roll of film, two lamp tests are made. One of these tests goes to the laboratory with the "selected" takes and the other is held with the "hold" takes.

In case any of the "hold" takes are later sent to the laboratory for processing, all or part of this second lamp test is included with the film so it may be developed by the laboratory to set the developing time. The "hold" takes are held for a period of thirty days at the end of which time they are turned over to the Test Camera Department or Cutting Department. The Test Camera Department makes use of the long takes for photographing the original pencil animated drawings for test reels. The sound-track on the edge of the film is blocked off by the projection aperture, so is not seen. The Cutting Department uses a great deal of film for leader in animation tests and re-recording reels.

About a year ago we started photographing the take numbers in the sound-track area of the film, so we now have no visible numbers for the breakdown man. However, we still notch between takes so the breakdown becomes only a problem of accurately counting the notches from the end of the roll.

* Presented before the Pacific Coast Section meeting, Hollywood, May 25, 1943.

** Sound Department, Walt Disney Productions, Burbank, Calif.

Since the institution of this breakdown procedure the Studio has saved many thousands of dollars as the film itself is salvaged for further use and the cost of processing "hold" takes is eliminated. So far, we have never been able to completely supply the needs of the Test Camera and Cutting Departments.

FILM CONSERVATION METHODS AT WARNER BROS. STUDIOS*

G. M. BEST**

In conservation of sound-track negative raw stock at Warner Bros. identification of the start of each take is made by the recording machine operator, who nicks the edge of the negative with a special punch. This involves opening the door of the recording machine, but in RCA equipment only one foot of film is fogged, resulting in a minimum of waste. Scene and take numbers are marked on the film with soft lead pencil, these marks being plainly visible to the breakdown operator, who passes the film through his gloved hand and stops at each nick. A recording card accompanies each roll that passes through the recording machine, and on this card the recorder marks whether the scenes are non-print, hold or print. All non-print are marked with an "X," while hold or print takes are marked with the letter "O," followed either by the words "print," or "hold."

All breakdown and splicing are done by the laboratory where a special dust-free room equipped with rewinds, safelights, storage racks, and standard Bell & Howell splicing machines is available at all times. The laboratory sends only the print takes through the developer, retaining the non-print takes on a large rack in the breakdown room until 72 hours after they have been received, at which time, if no order for development of any of them has been received through regular channels, they are spliced into 1000-ft rolls and sent to the printing room. Hold takes, which amount to about 15 per cent of the total footage shot on the average Class A picture, are sent to the vaults and stored away until a committee representing the main office in New York has screened the completed picture, and has approved it for release. A copy of their letter of approval is routed through the proper channels and authorization to splice

* Presented before the Pacific Coast Section meeting, Hollywood, May 25, 1943.

** Sound Department, Warner Bros. Pictures, Inc., Burbank, Calif.

the hold takes is then issued. This may take place many months before the picture is released and certainly never after the release date. This method reduces to a minimum the amount of film stored at any time, and provides for immediate use of fresh spliced negative while the emulsion is still new.

The splicing of the non-print takes is done by the breakdown operator during those hours after he has completed his breakdown work, and also by other members of the laboratory personnel when they can be spared for the work. Spliced negative is used for (a) all sound-track Dailies, regardless of their character, and (b) scoring composite dupe negative and two prints therefrom.

This uses all the available spliced negative, and where there is insufficient stock of this type for printing the Dailies, new stock is used for them. The set-up at Warner Bros. provides a composite dupe print of the cutting picture and sound prints for the Music Department and another for the Dubbing Department, so that the cutting prints are not used after the picture is approved for scoring and dubbing. This requires a footage equal to three times the length of the picture, and attempts have been made to use the dupe negative as a print for one of the departments, but so far with little success.

All separate sound-track prints, regardless of their purpose, have an exposure 150 mils wide of opaque density, printed on the edge opposite the sound-track. This permits the use of all prints, after they have served their original purpose, as black leader for the Dubbing Department. Thus all prints which would ordinarily be discarded, trims, transmission tests which are run once and then thrown away are all used as black leader. The Dubbing Department splices this film into 1000-ft rolls and reverses the direction, issuing it to the effects cutters as required. Tracks which are stored away for several years and then destroyed when there is no further possibility of using them are salvaged to the extent of cutting out the long, unbroken sections and sending them through the wash tanks in the laboratory to give the film new life, and are used again as black leader. In this way, no raw stock of any kind is ever fogged and developed as black leader. Each sound-track printer has a black leader fogging device as a built-in feature, and its function is automatic and constant. The question might arise as to what would happen if the printing machine operator left this light on while printing composite prints. The answer is that it *has* been done,

but the same man never does it twice for obvious reasons. Hence, little trouble has resulted from this fogging light while printing composite prints, and its presence on the printer can be disregarded.

Short ends of sound-track negative that have not been run through the recording machine are spliced into 1000-ft rolls by the Sound Department darkroom attendant in his spare time. They are segregated as follows:

(1) Rolls having splices from 10 to 25 feet apart; playbacks from stages for cutting purposes only.

(2) Rolls having splices from 50 to 100 feet apart; screen tests and Sound Department transmission tests.

(3) Rolls having splices from 200 feet up; narrations for shorts, cartoons, *etc.*; sound-effects.

Recording cards for this type of stock are of a special color, and are marked "Spliced Negative." Recordings of this stock are put through the developer last, after all the Dailies have passed through so that if there is a defective splice, no work that represents a large investment is lost. In the three years in which this system has been in use, there have been but two breaks in the developing machine because of a defective splice, and neither caused any serious loss of time or money.

It might be noted here that Warner Bros. Laboratory uses the metal patch method of splicing negative passing through the developing machine. This requires that the developed negative be broken down and reassembled with standard Bell & Howell splices before it can be printed.

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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 (not 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. Sound-Film

Approximately 500 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 10,000 cps.; the constant-amplitude frequencies are in 15 steps from 50 cps. to 10,000 cps. Price \$37.50 each.

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.

Statement of the Ownership, Management, Circulation, *Etc.*, Required by the Acts of Congress of August 24, 1912, and March 3, 1933, of *Journal of the Society of Motion Picture Engineers*, published monthly at Easton, Pa., for October 1, 1943.

State of New York }
County of New York } ss.

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Harry Smith, Jr., who, having been duly sworn according to law, deposes and says that he is the Editor of the *Journal of the Society of Motion Picture Engineers* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), *etc.*, of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

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Sworn to and subscribed before me this 4th day of October, 1943

(Seal) Jesse F. Tompkins
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(My commission expires March 19, 1944)

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

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RCA AUDIO CHANALYST

A NEW INSTRUMENT FOR THE THEATER SOUND ENGINEER*

ADOLPH GOODMAN AND EDWARD STANKO**

Summary.—*Proper service and maintenance of theater reproducing equipment has been an important consideration in bringing the art to its present high state of development. Improved service instruments and techniques have been necessary to keep pace with the rapid improvements made during the past decade and will continue to be important factors in the post-war period. The instrument described here is a new departure in the field of service as applied to theater equipment.*

Parallel with the advances in projector and sound equipment design has been the improvement in the sound service engineers' technique and equipment. As new developments occurred in the art, more precise adjustments of the sound-reproducing apparatus were required to give the audience the realism demanded by modern recordings. The service organization has responded to the more rigid requirements with improved tools and technique. Many new instruments were made available, such as the cathode ray oscillograph, the special power level indicator, the high impedance analyzer, and the flutter indicator. In addition, new types of test films were developed to provide complete overall check and calibration of the sound apparatus.

With the many new instruments available, there came a demand for a light, compact test instrument that would incorporate the functions of many of the meters now carried by the engineer. Through the facilities of the RCA Engineering Division and the practical knowledge gained by field engineers, the requirements for such an instrument were met by the RCA audio chanalyst.

Not only does this instrument fit the needs for compactness and efficiency, but it offers an entirely new service technique, known as audio signal tracing. With existing methods, tests are performed on the complete system or units under static conditions. The new

* Presented at the 1942 Spring Meeting at Hollywood.

** RCA Service Co., Inc., Camden, N. J.

method of signal tracing permits tests and checks to be performed on the units, while each unit is in operation under dynamic conditions.

With this instrument it is possible to locate sources of noise in audio circuits, determine cause of inoperative amplifiers, and locate the source of audio oscillation. In addition, it will measure power output in watts, a-f, a-c and d-c voltages, over-all gain, gain per stage, impedance, capacity, and resistance. It will supply fixed audio frequencies. It may be used to check phase inverter circuits,

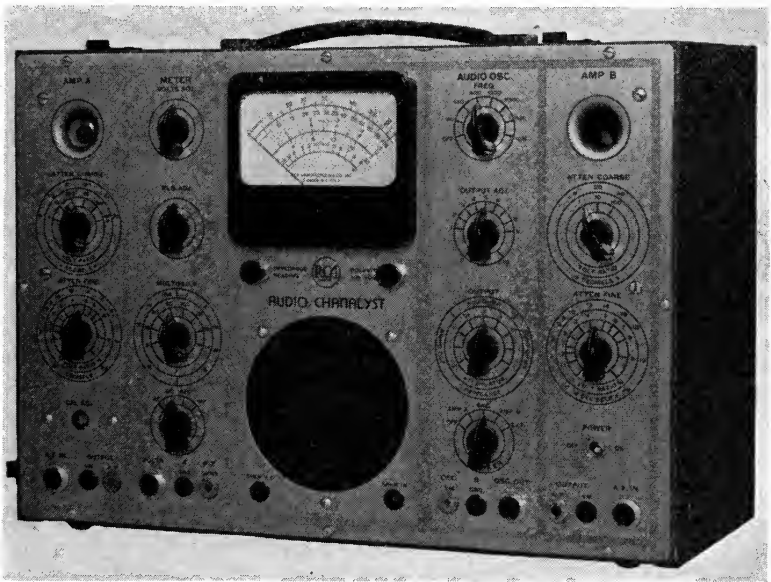


FIG. 1.

power supply units, microphones, phonograph pick-ups, and numerous components in the sound system.

The audio chanalyst, which is housed in a metal case, consists essentially of two calibrated amplifiers, a permanent magnet speaker with associated amplifier, an audio-frequency oscillator and an extremely sensitive electronic voltmeter. The complete unit weighs 35 lbs and the dimensions are: height, $12\frac{5}{8}$ in.; width, 18 in.; depth, $9\frac{5}{8}$ in. A source of power of 115 volts a-c, 60 cycles, is required for operation of the instrument. All controls and indicator devices are mounted on the front panel, easily accessible for operation. Fig. 1

is a front view of the complete unit. Fig. 2 is a view of the interior, and Fig. 3 shows the connecting cables for the audio chanalyst.

Amplifier channel *A* is a three-stage high gain, resistance-coupled amplifier, the output of which is impressed on an RCA 6E5 Magic Eye tube. This amplifier is provided with two calibrated controls for adjusting the signal level. Amplifier channel *B* is a single-stage resistance-coupled amplifier, the output being rectified by one diode

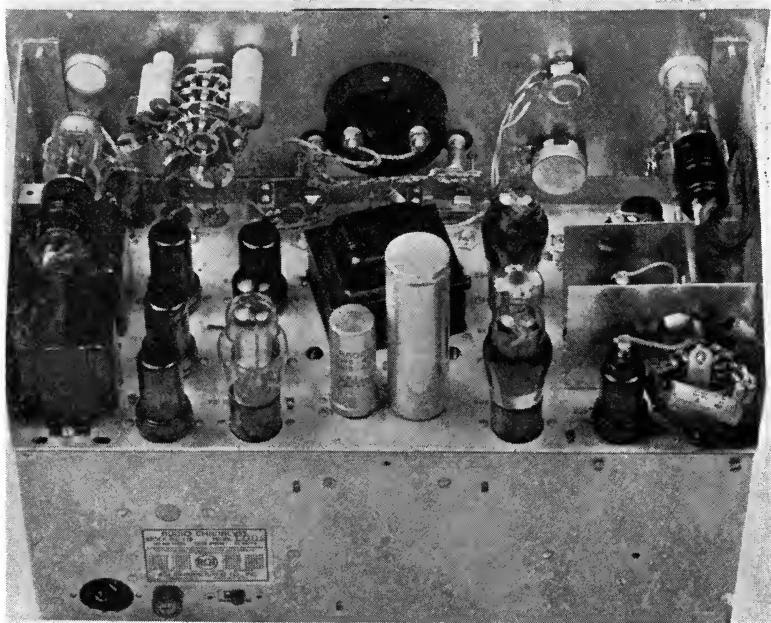


FIG. 2.

of an RCA 6H6 tube, and the signal impressed on an RCA 6E5 Magic Eye tube. This amplifier is also provided with two calibrated signal controls. The speaker channel amplifier is a single-stage amplifier transformer coupled to a permanent magnet speaker.

The electronic voltmeter incorporates two RCA 6G6 tubes in a new push-pull balanced electronic circuit. The RCA 6X5 is used for rectifying a-f and a-c signals. The input resistance of this meter for d-c ranges is 20 megohms, and 1 to 2 megohms for a-f and a-c ranges. The a-c voltmeter is furnished with a decibel scale having a range from -20 to $+9.2$ db (0.006 milliwatt level across 500 ohms). The total

over-all range when used in conjunction with the channel amplifiers is -80 to $+49$ db in 11 ranges.

The sensitivity of the electronic voltmeter is 5 volts full scale on both a-c and d-c and has 8 ranges permitting voltage measurements to be made on circuits as high as 1000 volts. It will also measure resistance values to 400 megohms and impedance values to 400,000 ohms. The frequency characteristic is flat up to 20,000 cycles per second. A fixed frequency audio oscillator provides the following

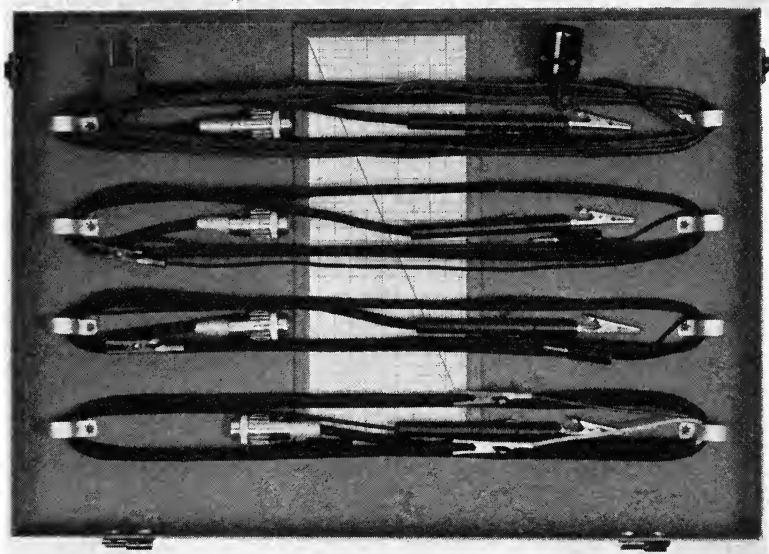


FIG. 3.

frequencies: 60, 150, 400, 1000, 2500, 5000, and 10,000 cycles per second. A tapped output transformer allows selection of the following impedances for matching line and amplifier input circuits: 250, 500, and 5000 ohms on balanced lines and 62.5, 125, and 1250 ohms on one-side grounded circuits. One RCA 5Z4 tube is used as a rectifier, and an RCA VR-150 regulator tube is used to stabilize the B supply voltage for the oscillator (Fig. 4).

When using the audio chanalyst for signal tracing, the various units are arranged so that channel A amplifier, and its associated Magic Eye, may be used individually or in cascade with channel B , and its

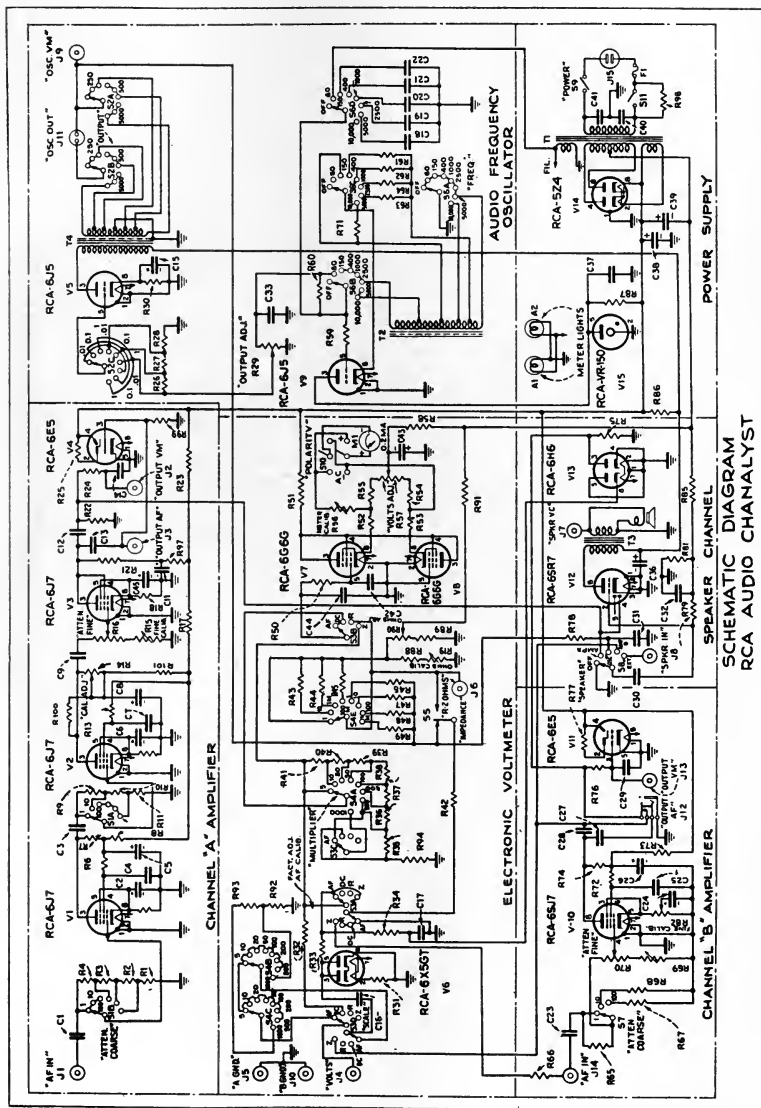


FIG. 4.

SCHEMATIC DIAGRAM
RCA AUDIO CHANALYST

Magic Eye, or a combination of *A*, *B*, and speaker channels, can be used simultaneously with the electronic voltmeter. Thus, the presence or absence of a signal can be observed visually at the output of either channel *A* or channel *B* amplifiers, or it can be measured electrically by the meter, and at the same time, heard aurally on the speaker. This combination of visual, quantitative measurements, and aural signal reproduction will instantly enable the engineer to determine where the signal is, and where it diminishes in strength, and how much (Fig. 5).

In audio-signal tracing and trouble localizing, the amplifier under test is set up for normal operation, and the power turned on so that all measurements can be made under actual operating conditions. A 400-cycle signal from the audio-frequency oscillator is fed to the input of the amplifier under test. If a high-gain amplifier is being checked, the signal should be further reduced by an attenuator between the oscillator and amplifier input.

Channel *B* amplifier may be connected to the output of the amplifier being checked. When the signal at the output of the amplifier under test is absent, distorted or noisy, as indicated by channel *B* amplifier Magic Eye, the probe on channel *A* amplifier is used to locate the point where the signal departs from normal. This can be detected by observing the amplified signal as the signal tracing probe is used to trace the signal from the amplifier input throughout the various parts of the circuit, step by step. The speaker channel amplifier may be used to check the signal at the output of either *A* or *B* channels by means of a switch provided for this purpose.

The electronic voltmeter can be used to check the over-all signal or gain of a single stage while the source of trouble is being located. When the trouble has been traced and localized to some particular part of the circuit, or component, measurements can then be made to determine the departure from normal by measuring the voltage, current, resistance, capacitance and inductance of the component suspected of causing the trouble. All of these tests can be made without resorting to other instruments as the units have been so designed and arranged that they can be used for making individual measurements.

When tracing signals in amplifiers requiring more channel gain for probing, both *A* and *B* channels can be connected in cascade. By means of calibrated gain controls on the audio chanalyst, and calibrated meter scale on the electronic voltmeter, the gain per stage, or over-all gain, can be measured in voltage gain or directly in db.

To locate noise in an amplifier, it is not necessary to use a signal from the audio oscillator. The noise itself can be considered a signal, and the probing amplifier gain controls are set for maximum gain. The procedure for locating noise is practically the same as that used in signal tracing. If there is noise present at the point where the probe is located, the noise can be observed by a flickering of the Magic Eye or heard on the speaker. Point-to-point checking is followed through until the source of the noise is located.

Checking push-pull stages of an audio amplifier is a comparatively simple test. The same set-up is used as for signal tracing and noise detecting. The signal is traced from the plate of the preceding tube through the push-pull transformer to the grid of each push-pull stage. The signal voltage at each grid should be the same if the amplifier stage is operating normally. Inequality of signal voltage, or absence of a signal at either grid, indicates trouble somewhere in the circuit.

If a phase inverter circuit is operating normally, the signal voltage at each grid of the phase inverter tube will be the same. The signal voltage at the plates of the same tube will be the same as at the grids of the following output tubes. Any variation in signal level at any of the above-mentioned points should be investigated. Noise and hum levels can be checked using either the Magic Eye indicators, or the electronic meter, and speaker channel. Hum on the Magic Eye will be indicated by a fuzziness of the image, or it can be measured by the electronic voltmeter.

Intermittent operation of an audio amplifier is probably one of the most difficult troubles to locate. This intermittent condition may be difficult to trace with ordinary test equipment because instruments now used will not permit simultaneous signal checking at several different points in the amplifier without affecting the operation of the amplifier being checked.

With channel *A*, channel *B*, speaker channel, and electronic voltmeter of the audio chanalyst connected to four different sections of the amplifier under test, any intermittent condition can be isolated quickly. That section of amplifier in which a change of signal level occurs is indicated by either of the Magic Eyes or the electronic voltmeter, or signal output of the speaker channel.

Phonograph pick-up units can be checked easily by connecting them to either *A* amplifier, or *B* amplifier input and checking the frequency response with a constant frequency record. Distortion can be

checked audibly by switching the speaker channel amplifier to output of either *A* or *B* channels.

Capacitance and impedance measurements are made with the electronic voltmeter in conjunction with the audio-frequency oscillator. Calibrated charts are provided so that all tests can be converted to actual values. Suitable cables are supplied as part of the audio chanalyst for making all tests and interconnections between it and the unit, or units, to be checked. The audio chanalyst is not limited to the uses described in this paper. There are many other tests which can be performed and in practical application, no doubt many new uses may be found.

The compactness and flexibility of the RCA audio chanalyst, together with the many functions that it will perform, place this instrument far ahead of any test equipment that has been previously used for locating audio amplifier troubles.

EDITING AND PHOTOGRAPHIC EMBELLISHMENTS AS APPLIED TO 16-MM INDUSTRIAL AND EDUCATIONAL MOTION PICTURES*

LARRY SHERWOOD**

Summary.—Procedures and equipment used to edit 16-mm industrial and educational motion pictures are described. Various types of effects are explained and examples given of some use to eliminate excessive film footage.

Due to a long succession of involved circumstances, 16 mm has been regarded as a stepchild of 35 mm. The only logical reason must be that the film area is smaller, therefore everything connected with 16 mm must be smaller. Editing equipment, camera adequacy, projector efficiency; yes, even production technique must be in direct proportion to the film area.

When stated thusly, it seems almost ridiculous. Certainly, such reasoning is fallacious.

If one had an 8 × 10-in. portrait camera and desired to build a 35-mm miniature camera, would the procedure be merely to build the "mini" camera along the same lines as the portrait camera, with but one thing in mind—reduce in size the elements involved? Yet, regrettable as it may seem, this is what has happened to a large degree to 16 mm.

Due to these circumstances, those of us who are utilizing 16 mm for something more than a hobby have found it necessary to become protestants and attempt to develop or redesign much of the equipment, and likewise evolve a technique of procedure which will satisfy the needs of a relatively new and growing industry.

It must not be construed that what has been done is final, perfect, or in every instance completely satisfactory. Yet, it can be said without fear of contradiction that the methods, various types of equipment and procedures that have been developed, work.

Therefore, it is without prejudice or any attempt to convey a finality in these factors that the following are commended to you.

* Presented at the 1942 Fall Meeting at New York.

** Director of Productions, The Calvin Company, Kansas City, Mo.

First, let us study in some detail a satisfactory 16-mm editing room and equipment.

The room should be small, perhaps 9 ft sq, with soft green walls, and well ventilated.

On the walls are fastened tiers of 1 × 2-in. boards parallel to the floor and into which nails or pegs 3½ in. apart are driven. By thus spacing the nails and boards 100-ft 16-mm projection reels can be placed upon them, as shown in Fig. 1.

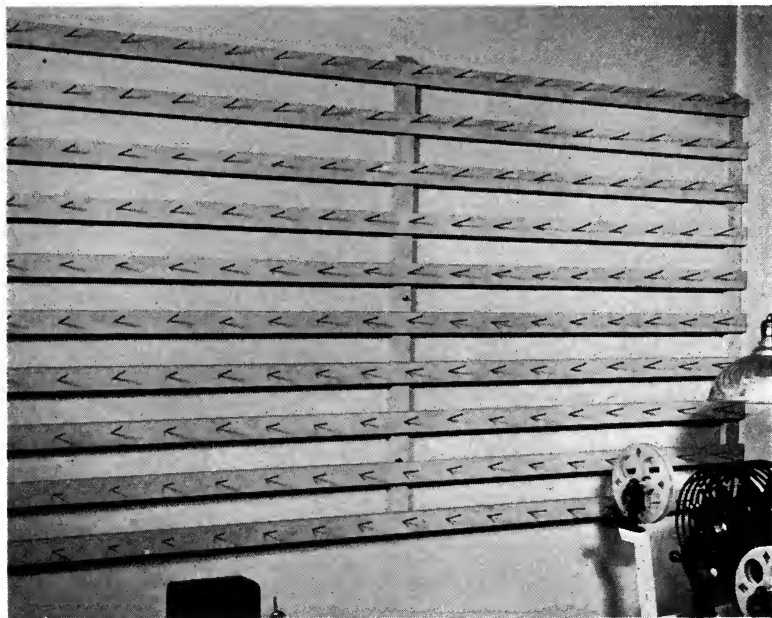


FIG. 1. Wall rack to hold 100-ft 16-mm reels.

The editing table, shown in Fig. 2, is desk high and well lighted. Attached to the back side of the table is a baffle board. In the left side in rows have been driven ten or twelve pegs or nails. These nails are arranged with sufficient room between them so that normal 100-ft reels can be placed upon them.

On top of the back baffle board is a small speaker. The table contains two drawers, one on each side. The left drawer holds an amplifier which is connected to the speaker and to a sound head taken from a Victor standard 16-mm projector, Fig. 3. This particular

sound head is used because it has proved by trial and error to be easy to handle and does the job of a good "squawker." The film can be easily moved back and forth across the drum in order to pick out particular words or phrases to form a guide for the cutting process.

This sound head is attached to a Bell and Howell 16-mm silent projector, both of which are synchronized so that the sound-track

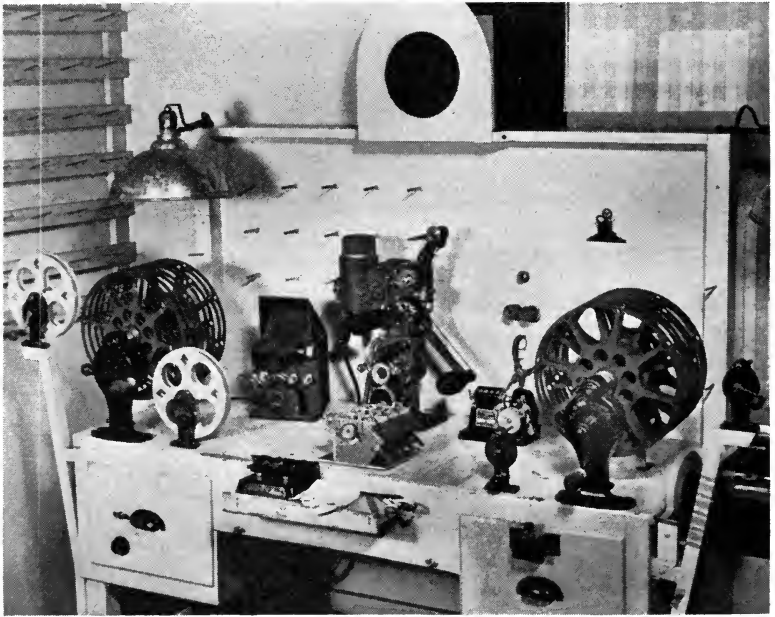


FIG. 2. Editing table.

and the film, when finally edited, can be checked carefully and accurately before sending to the laboratory for printing.

At each end of the editing table, four or six 800-ft take-up reels are mounted on shafts which allow them, when turned, to travel synchronously.

The synchronizing machine consists of four or six sprockets with the teeth on one side, as seen in Fig. 4. The sprockets are mounted securely on a shaft. This machine utilizes either silent or sound stock.

Fig. 5 shows the "editor," a standard Craig. It is suggested that the right spool under which the film passes be moved nearer to the

edge of the viewer. This lessens the tension on the film as it is being moved back and forth. Also, the roller on the left side, which creates the pressure against the film, should have attached to it a small lever or handle so that it can be moved up and down to facilitate removing the film. A Craig operates on the principle of a prism,

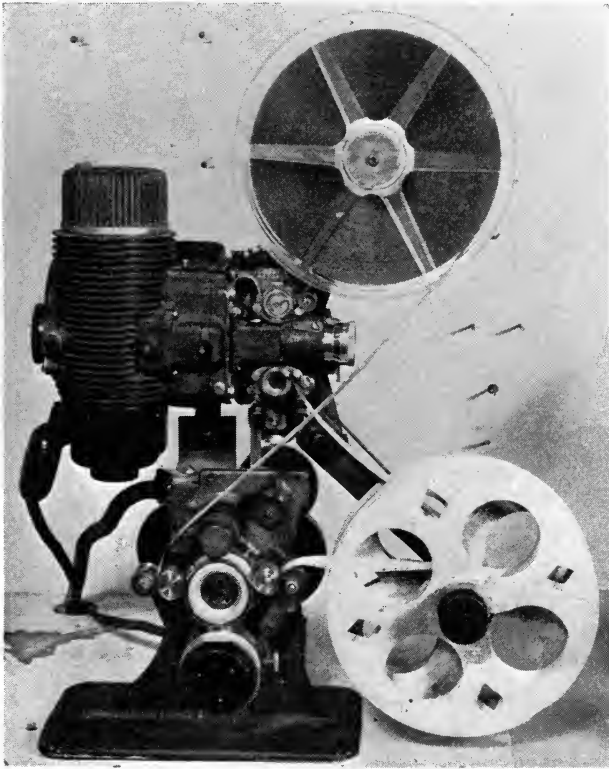


FIG. 3. Projector.

which enables the editor to see, with no confusion, each particular frame. This is very essential in cutting on action or movement.

It is also recommended that a foot switch be installed for better control of the light source thereby lessening the possibility of burning the film.

The splicer, shown in Fig. 6, is a Griswold 16-mm Junior—and there is that word “junior” again. When properly adjusted, it makes a

very fine, thin, yet strong and durable splice which does not show in projection.

A pair of good sharp scissors is a highly essential tool of a good editor. Ordinary emery boards, the very same used by any manicurist, are also a very efficient tool of the editor. There are various methods of removing emulsion from film; however, we have found that by scraping dry with an emery board which has been clipped off

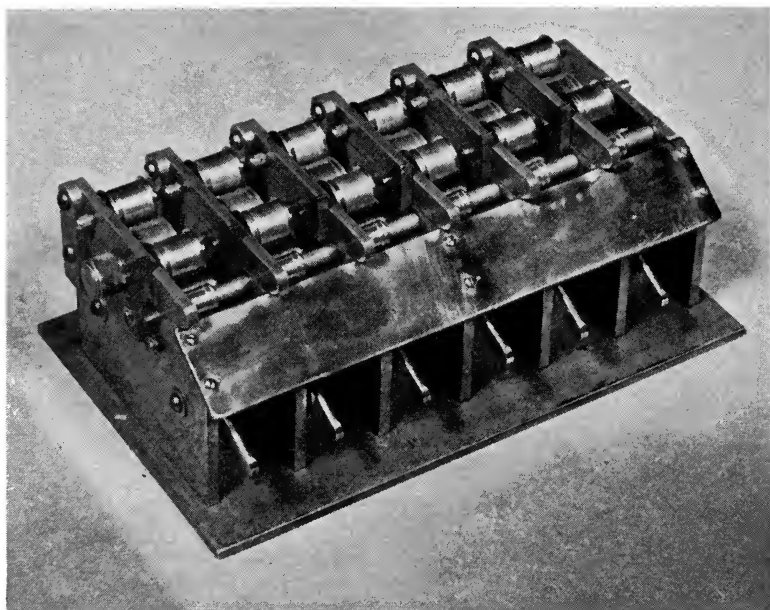


FIG. 4. Six-sprocket synchronizing machine.

with the scissors at an angle after each use, the emulsion can be removed completely and quickly for the splicing process.

With a small bottle of Eastman cement clamped on the side of the table to the right of the editor, a footage counter, and four other take-up reels, we have an efficient set of tools to begin the job of editing. A handy bin to hold 100-ft projection reels will facilitate the speed.

Before we begin a detailed discussion of editing, let us define it with regard to motion pictures. "Editing is an art—and we must call it an art—of piecing together with a splicer, an emery board, some

imagination, and a little cement a series of photographic scenes to form a clear, concise, and easily understood explanation of a particular subject."

In the industrial and educational motion picture field it is necessary to utilize various types of editing technique, such as all syn-

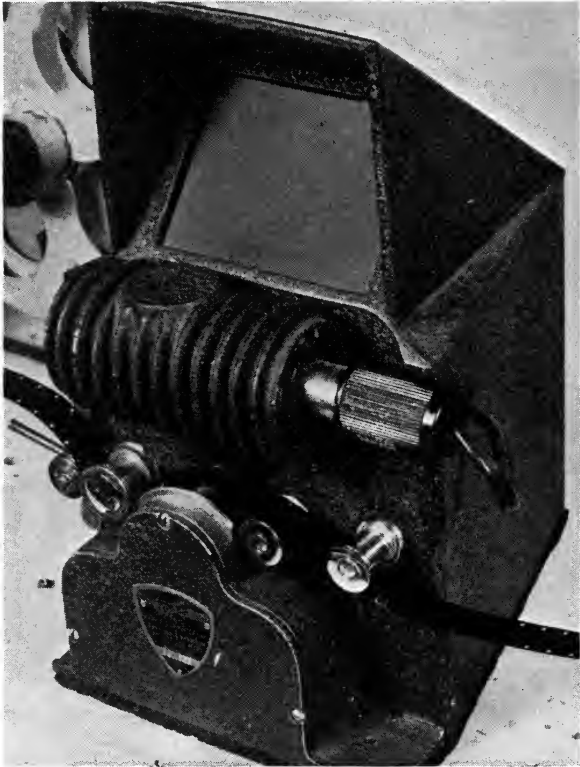


FIG. 5. Standard Craig editing projector.

chronous "shows," straight cut, or other types such as shows containing trick effects, sound effects, musical background, *etc.* Each requires a different type of handling. However for clarity let us assume that we are to edit a 16-mm color production with musical background, synchronized sound effects, narrator track, and with a few synchronized sequences. We obviously do not want to edit with original film of any type. Inasmuch as edge-numbering has not yet, we regret to say, become universal, we must develop a technique for

marking film. To do this, we begin with script or camera report made in the field at the time of taking the pictures; each scene is naturally numbered. We begin with any reel of the original film and edit out the scenes to be used in the picture, winding at the same time on a rewind, all those scenes we are not going to use, or as we choose to call them, the "overs."

As we identify all of our good takes, we wind each separate scene



FIG. 6. Griswold Junior splicer.

on a 100-ft reel, stick a piece of Scotch tape on the end of it, lap it back over the side of the reel and print the scene number or description of that particular scene on the tape. Reel by reel, as each scene is identified and marked, they are tossed into a cardboard container at the side of the editor. This procedure is continued until each scene, photography, sound effects, and voice, have been properly identified and numbered.

The next step is to take the box of identified reels and place each reel on the correspondingly numbered peg on the wall, as seen in Fig. 7. After each scene has been identified and hung on its respective

peg, the editor may rearrange the sequences or individual scenes. In other words, with each reel properly identified and numbered, the editor can see his whole show scene by scene, sequence by sequence.

The next step is to splice these scenes together in sequence, beginning with reel one, until there are approximately 390 ft on a reel. After this is done the reels of film are sent to the laboratory and a

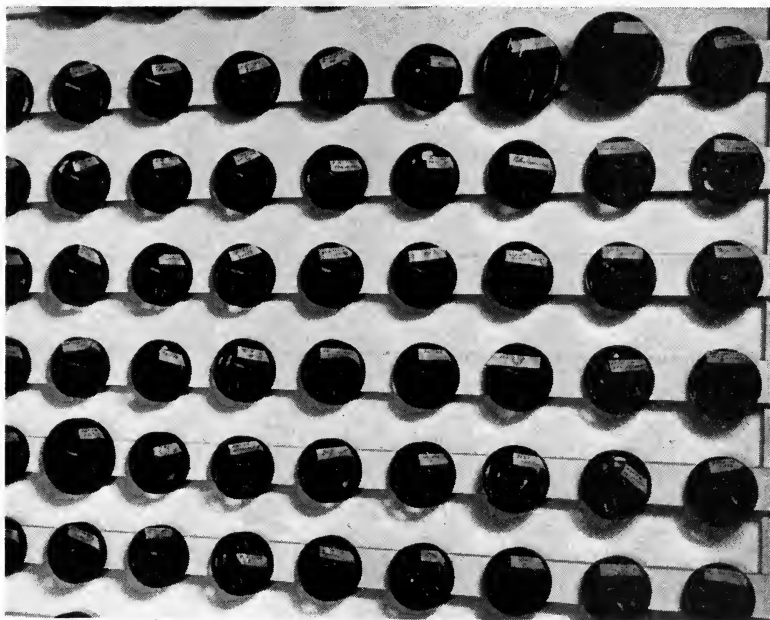


FIG. 7. Identified scenes placed on the wall rack.

black-and-white work-print is made from them. The same procedure is followed with the synchronized sound-track and sound-effects track. When this material is returned from the laboratory, the editor has the original photography, sound-effects track, synchronized voice track, and work-prints of each.

As mentioned above, due to the lack of universal edge-numbering a technique was developed that enables the editor to synchronize the work-print with the original photography. This is done by putting the strips of film into a synchronizing machine and then nicking a frame, using a small built-in nicking device, in each strip

synchronously, as shown in Fig. 8. This notch then acts as a guide for synchronizing the original material with the work-print, after the work-print has been completely edited. In other words, this notch acts as a guide in the final process of matching the original photography with the work-print.

Upon completion of this operation, the original photography,

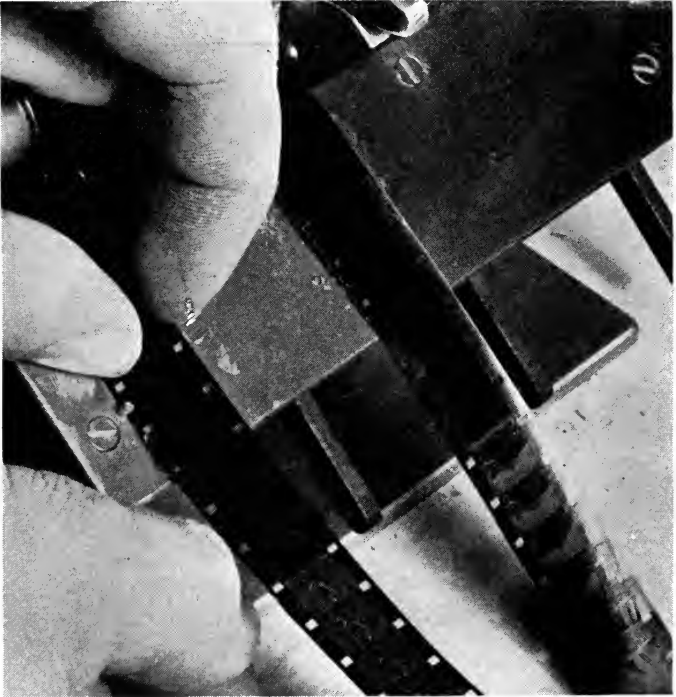


FIG. 8. Notching device on synchronizing machine.

original sound-effects track, and original synchronous voice track are put away, and the editing of the film is begun, working entirely with the work-prints.

The procedure is to edit the picture in the normal manner, with one exception. One foot of film is cut off at the end of the scene and 1 ft at the beginning of the succeeding scene between which it is desired to produce an effect. In so doing, there will be a surplus of 1 ft of original film at the end of one scene and the beginning of the succeeding scene, which allows an overlap of 2 ft in the original.

Simultaneously, the sound-effects and voice tracks are edited into the picture. After the film is so edited and all sound-tracks matched, this work-print is utilized as a guide for the narrator, and further as a guide for the music track. The music track, sound-effects track, and the narrative track are then re-recorded and balanced to produce the final sound-track that is to be printed to the picture.

It is difficult for me to refrain at this time from discussing the

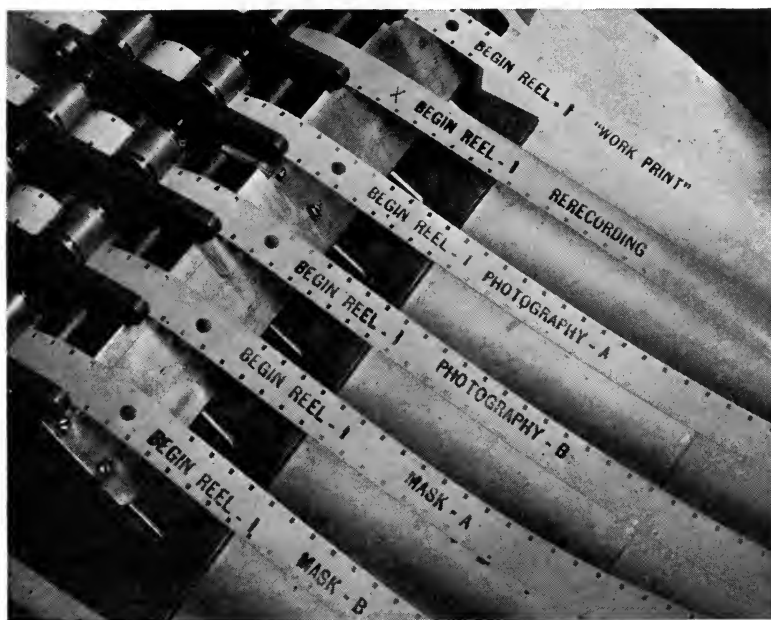


FIG. 9. Leaders showing punched synchronous frames.

merits of the direct positive system, or the reversal system as compared with the negative positive system; and also variable area with variable density sound-tracks. To save myself involvement, I will leave that to my engineering friends. Suffice it to say that we have found the former in both cases to be much more satisfactory.

Now, that the work-print is edited, the music track re-recorded, the narrative track recorded, the sound effects all re-recorded and combined into one film, we are ready to enter into the final stages of editing. These final stages consist of matching the original photography to the work-print, and at the same time preparing the traveling mats which contain the effects—and therein lies a tale.

It is somewhat difficult to explain the method of procedure, yet in reality it is extremely simple. The original photography will be edited into two strips of film, which for convenience we will call *A* and *B*. The mats will also be edited into two strips of film, coinciding with the *A* and *B* photography. In short, there is a strip of *A* photography and a strip of *B* photography, and a strip of *A* mat and a strip of *B* mat, shown in Fig. 9. We then make up leaders, place

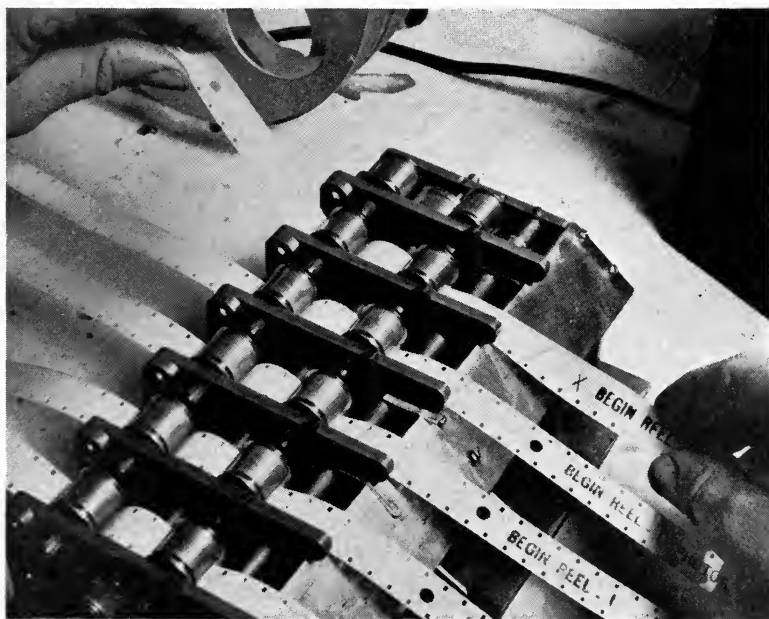


FIG. 10. Re-recorded track showing "sync" hole.

them in a synchronizing machine with the work-print and punch a particular, synchronous frame in each strip.

There is one exception, and that is the re-recorded track which is marked with the cross and the "sync" hole placed 25 frames down. This is done so that the final print will carry the sound 25 frames ahead. This will compensate for the distance between the projection light source and the sound light source. The leader is necessary for threading into the printer and in checking synchronization, Fig. 10.

The film is wound down to the first scene of the work-print; and to the leader marked "photography *A*" splice the first scene in exact

synchronization with the work-print. The synchronization is determined by the notches previously placed on the sides of the film, when working with film that is not edge-numbered.

To the leader of mat *A* is spliced a strip of transparent film, which in the printing process will allow the light to pass through this mat and print the scene on photography *A* on the raw stock. On photography *B* there is spliced the normal leader film, which in the case

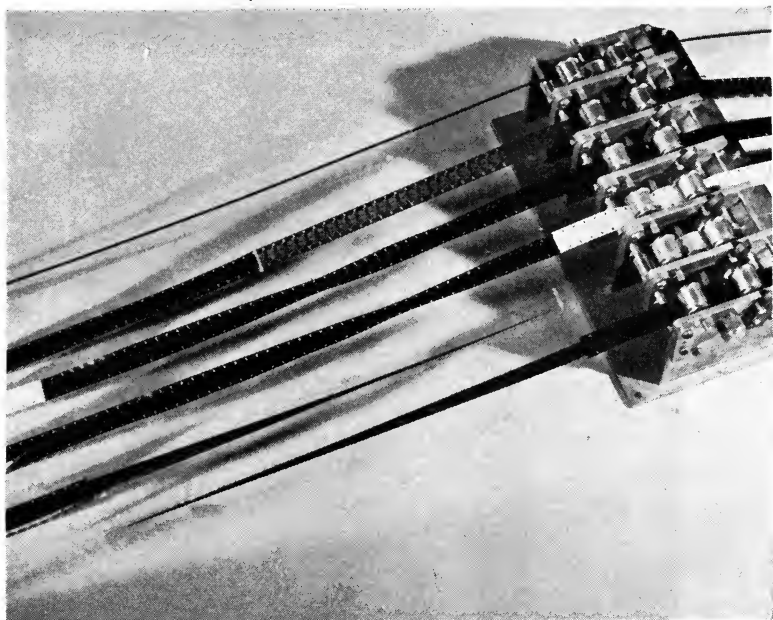


FIG. 11. Reading from top to bottom: sound-track, work-print, original photography *A*, original photography *B*, mat *A*, and mat *B*.

of exposed film is yellow in color. On mat *B* there is spliced a strip of black film. This black film is produced merely by running the exposed film through normal processing. The result is that the yellow leader on photography *B* will be blacked out. The film is then rolled down to the second scene and matched to the work-print by the same method as in matching photography *A*.

There is an overlap of 2 ft in photography *A* and *B*. Now, to insert a mat: these mats can be made up in any form the imagination can develop—lap dissolves, straight vertical wipes, horizontal wipes,

circle wipes, *etc.* For clarity, let us assume that a straight left to right vertical wipe, or effect, is wanted between the first and second scenes. This straight wipe consists of two pieces of film, one negative and the other positive. These mats are matched so that wherein *A* has a clear portion of film, *B* will have a black portion. The mak-

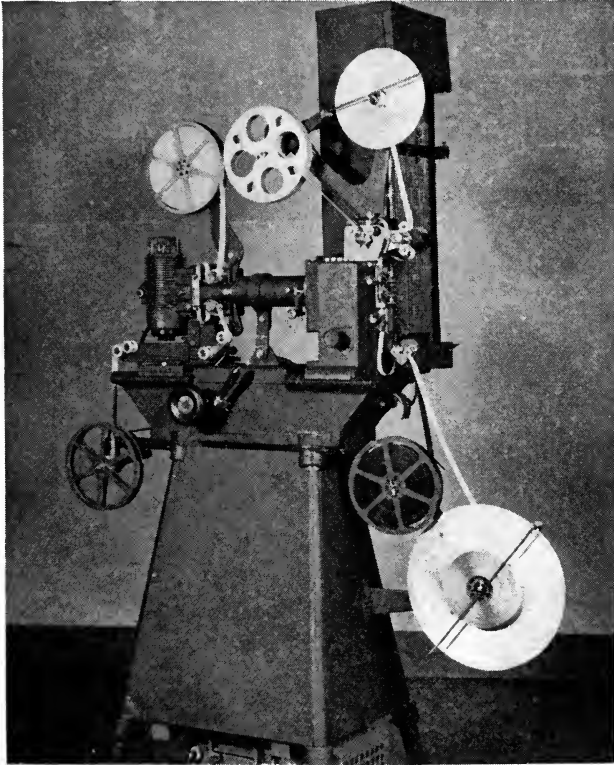


FIG. 12. Printer.

ing of these mats is a simple process and we will not take the time here to discuss the manner in which they are made (Fig. 11).

Now, to proceed from photography *A* to photography *B*: splice the part of the effect film with the greatest clear portion to the clear film of mat *A*; then, the positive mat with the greatest black portion is spliced to the black portion of mat *B*. Each and every effect is produced in this manner. In other words, wherever it is desired to produce an effect, the photography is moved from *B* to *A*, or *A* to *B*,

whichever the case may be, producing an overlap of film. Then an effect is inserted at that juncture in order to be printed.

In the printing process, Fig. 12, photography *A* and mat *A* are run synchronously and the light of the printer is allowed to pass through mat *A* and through photography *A*, exposing the picture on the raw stock. In other words, wherever mat *A* is clear and there is a picture on photography *A*, that picture will be transferred to the raw stock. When a mat presents itself to the printing light, it allows exposure to be made on the raw stock in direct proportion to the amount of clear film characteristic to that particular mat—only that portion of photography *A* at that particular juncture is transferred to the raw stock.

Then the raw stock is again exposed in the printer, utilizing photography *B* and mat *B*. The process is exactly the same as that explained for photography *A* and mat *A*. The result on the final print is the desired effect, creating a transition from one scene to another.

At this time, we should perhaps discuss the use of these so-called photographic embellishments. We choose to call these effects "photographic embellishments" simply because in most instances any other types of effects are not, due to inadequacy of equipment, plausible in 16-mm industrial and educational films. We have not found it necessary in the industrial field to utilize many of the photographic embellishments used by theatrical producers, such as involved or fancy montage effects, processed backgrounds, *etc.* An industrial and educational film might be differentiated from a dramatic or theatrical film in that, in most instances, the former is a picture of processes rather than of impressions. True, many industrial and educational films must create an impression; therefore it would be clearer to state it more simply and say that an industrial and educational film concerns itself with specific and detailed information rather than emotional and philosophical impressions. Consequently, we choose to call lap dissolves, various types of wipes and trick effects, *etc.*, simply effects. We do not like to refer to these effects as embellishments for they are rather a necessity—and, if you please, an economic one.

In fact, it is possible to conceive that effects of the nature under discussion can within themselves be potential educational factors. One illustration: it is a matter of record that by habit the human eye travels to the left when presented with a screened object. Suppose it becomes necessary to direct the attention of the audience to the

right side to derive the maximum educational value from the scene. We merely introduce the picture with a vertical right to left wipe. The action of the effect draws the attention to the right side of the frame, thereby directing the attention of the audience, and obviously minimizing the normal reaction of left to right visualization. In so doing, perception is improved and memory enhanced.

It is practically impossible to use too many effects, if they are used intelligently and judiciously. An effect may be compared to punctuation in writing prose or poetry. It is possible to use a great deal of punctuation in writing an article or essay, but that punctuation becomes ineffective the moment it becomes excessive. The same idea may be expressed with regard to the utilization of effects in editing an industrial motion picture. Industrial and educational motion pictures by their very content need such photographic effects much more than a theatrical or emotional type of picture, simply because most industrial or educational pictures do not, by their very nature, fall into connected and related sequences.

There are many things, due to the time element, which must of necessity be left out, or perhaps left to the imagination of the audience. To illustrate: if we want to show the manner in which a dust cap is put on the valve of a tire (which at this particular time we would like to look at), it is not necessary to show each step of the process of how the dust cap is screwed down on the tube, but we can take the cap and start the process, then through the use of a lap dissolve or some significant effect, eliminate the time element and make a scene that is short, yet clear and concise in every detail.

Yes, effects may be likened to punctuation. What can be said of one can be said of the other. If punctuation in the sentence is obvious to the reader, it ceases to be good punctuation. It loses the power that should belong to it. The same thing can be said of effects. Any effect that is obvious is not a good effect, because the moment the audience becomes conscious of the transition created by an effect, that effect begins to detract from the intent of the story and from the intent of the effect. Therefore, in saying that it is almost impossible to use too many effects, it is to be thoroughly understood that this statement does not hold true unless such effects are used judiciously.

Now, there are various methods of using effects in order that they do not become obvious. As an illustration, suppose a picture of two types of files, side by side on a bench, is wanted. It is desired

to explain the difference between a single-cut bastard cut file and a double-cut bastard cut file. Upon examining such a file, it is evident that the teeth of the file are microscopic. First, a scene is taken, perhaps a medium close-up, as an establishing shot in order that the audience may know at what they are looking. Now, it is necessary to go farther than that and bring the audience to a microscopic viewpoint. To use a straight vertical wipe at this place, or a lap dissolve, or a horizontal lift wipe, or any other type that the imagination may conceive, would be in poor taste and would immediately confuse the audience.

However, if one uses a circle wipe and in shooting the picture has a hand with a pencil come into the establishing shot, then, with the use of the circle wipe, have the pencil come into the microscopic close-up in the same manner, the circle wipe will create in the minds of the audience the feeling that they are seeing these files through a microscope. This is one example of judicious use of a particular effect.

As another example, we have a train sequence or montage in which it is desired to create the idea of travelling over some distance. A straight vertical wipe between each shot of the sequence or montage, travelling in the same direction as the action on the screen, will create in the minds of the audience the idea of continuous travel. Now, if this vertical wipe should be edited into the picture in such manner that it is contrary or against the movement, the audience is again confused. While if the effect is placed in the picture so that it moves with the action, the audience at no time will become conscious of the fact that an effect has been used.

Another advantage of effects is the elimination of excessive footage. Those who have had experience in the industrial or educational field realize that this is one of the greatest problems confronting the educational and industrial motion picture producer; therefore, a few examples of how an effect may be employed to reduce footage will be discussed.

Suppose we have one scene of a close-up of an entrance to a building and in the shooting of the picture want the close-up of the entrance to be followed by a low-angle shot to the top of the building. If the building is of any size, it would take from 20 to 25 ft of film to execute this upward "pan." The same effect can be created by inserting a horizontal lift wipe between these two pans. The audience will not be conscious that an effect has been used, and it is possible to cut down 12 or 13 ft of film in this one sequence.

As another example, and there are hundreds of such, let us assume that we are shooting an oil drill operation and want a low camera angle of the "Kelly" being hoisted into the tower and then lowered with the pipe into the hole. If such an operation is observed, it is realized some little time elapses from the time the Kelly is pulled to the top of the tower until it lowers the pipe into the hole. The camera shows the cable and Kelly drawing the pipe into the tower, then a lift wipe can be used to follow it up, and the Kelly can immediately lower the pipe into the hole. This would realize a saving of 20 to 25 ft of film.

The question no doubt immediately arises, "Why not use a lap dissolve?" The answer is simple. Both shots are taken from the same angle. A lap dissolve inserted at this juncture would create an image displacement, because it would be physically impossible to pan up with the camera, then pan down and utilize this extra footage in a lap dissolve without losing registration or having a change of camera position, though it might be very slight.

A generality that may be of value concerns itself with where and when to use effects. We have found it good general policy to use a wipe of one sort or another—most of the time a conservative left to right wipe—to introduce more or less unrelated sequences, and then within the sequence use lap dissolves to show the passage of time or to eliminate footage. Of course, this is a general statement and can not be expected to meet all requirements.

I wish that I were in a position today to give you some statistical data regarding the use of certain types of effects. There are a number of questions that arise. First, should you ever in an industrial or educational motion picture use a right to left wipe? Should you ever use a split scene? What portion of the picture is lost by the use of a particular effect? What is the percentage of confusion or lack of confusion between a straight cut picture and one using effects?

I hope by this time next year to be in position to offer you such statistical material or data. I have been invited to collaborate in research, and am now in the process of working with Dr. W. I. Gooch, Director of Education for the Boeing Airplane Plant, and Mr. Russell Mosser, in charge of visual educational training of the Boeing Company.

We hope by these studies mentioned to clarify a great many problems regarding industrial and educational films. We have the not too vain hope that we will be able to clarify at least a few of the prob-

lems involved regarding industrial and educational motion pictures.

It is the hope that soon even greater strides will be made by the engineers of the industry in developing better and more efficient equipment.

Sixteen millimeter is a growing and progressive industry—it is progress. I think that it was not said—but should have been—in McGuffey's first reader that "Some individuals may retard progress, but no group of individuals can ever stop it."

RECENT DEVELOPMENTS IN SOUND CONTROL FOR THE LEGITIMATE THEATER AND THE OPERA*

HAROLD BURRIS-MEYER**

Summary.—A series of experiments involving the control of reverberation and spectrum as applied to both music and speech, has brought to a conclusion the research project directed toward the complete control of the auditory component of legitimate or operatic production.

Before this Society, at the Rochester meeting last year, I had the privilege of demonstrating Synthea, the acoustic envelope designed for concert use. During that same season and the one just past, the research enterprise which fathered Synthea tested in production a number of other gadgets and techniques designed to complete our job of subjecting all sound in the theater to electronic control. If you really want to, you can now make the audience hear just what you desire, the way you want it. The artist has complete control of the auditory component of the "show." It is gratifying to have accomplished this, even though priorities and artistic conservatism will delay the full exploitation of electronic means of sound control. This technique will achieve its maximum usefulness only when the motion picture has facilities to employ it and make it an integral part of our dominant art form.

The control of reverberation has been successfully undertaken in motion pictures and radio. The devices involved have included the echo chamber, vibrational transmission along springs, and various means of recording and near-instantaneous playback. The problem in the legitimate theater is complicated by several conditions not encountered in radio or motion pictures: first, the legitimate theater, or opera house, usually has longer reverberation at most frequencies than the average motion picture theater, or the room in which the radio receiver is located; second, the difference between the sound intensity of the show and the background audience noise level is generally less than in the case of motion pictures; third, the audience

* Presented at the 1942 Spring Meeting at Hollywood.

** Stevens Institute of Technology, Hoboken, N. J.

at a legitimate, or operatic production, conventionally demands much greater subtlety and flexibility in the auditory component of the show than is demanded of any other medium.

Devices for control of reverberation in the legitimate theater and the opera must, therefore, possess ultimate flexibility. They must be able to reproduce reverberant conditions within the acoustic limitations of the theater, including echoes found in structures and in nature, and must be susceptible of producing arbitrary, suggestive, or exaggerated phenomena in conformity with artistic demands, which do not necessarily involve imitating nature.

The only devices capable of filling these requirements employ the principle of recording and multiple playback. In fact, for the satisfactory interpretation of music, Leopold Stokowski has suggested that it is probably worth the effort to divide the frequency spectrum into a number of zones and have independent control of the apparent decay time in each zone. Such a technique makes possible the performance of any piece in the manner intended by the composer irrespective of the reverberation of the place in which it is performed, and will give added scope for new interpretations.

The first episode employed to study the theatrical use of reverberation control was Widor's *Toccata in F*, to which we added enough reverberation to approximate that in the Church of St. Sulpice. The experiment was welcomed with considerable enthusiasm by all but a few members of the audience that included a number of eminent musicians. Two members, who had heard the *Toccata* played in St. Sulpice, declared we had reproduced exactly the acoustical conditions obtaining there. I doubt we did as well as that. Audience enthusiasm may be attributed to these factors: first, the *Toccata in F* is in itself a most effective showpiece, and it was staged for a maximum effectiveness within the limitations of the theater; second, its performance by the organist was excellent; and, third, the piece was played at peak levels high enough to make almost anything exciting. Those of you who heard the same piece played by stereophonic recording at the Eastman Theater last year, or at Carnegie Hall, or at Pantages the year before, can easily realize what controlled reverberation could do for it.

Reverberation in our test was accomplished by recording on steel tape by the device developed by S. K. Wolf. The reverberation machine was so arranged that the first playback occurred $\frac{1}{8}$ of a sec after recording of the original sound, and 3 sec passed before the last play-

back dropped below audibility. The first playback was 6 db below original level; the last started 15 db below. There were 9 intermediate pick-ups, adjusted in point of time to conform to acoustic conditions of the theater. The first playback had to be delayed to avoid feedback until the level of the normal reverberant sound in the theater had dropped 6 db.

The *Toccatà* was originally played on the Paramount Theater studio organ, recorded on a vertically cut disk, and played back over 52 speakers located in the house and stage. The reverberation playback was through a separate set of speakers to contrast in direction with the original sound. The quality of the recording was sufficient to deceive the audience, who believed a real organ was being played in the theater. The fact that the piece as played had almost no pauses made it sometimes difficult to perceive the dying away of single notes. Applause followed so soon after the final chord that its reverberation was never perceptible for more than the first second. Because of these conditions, it may be argued that reverberation can be even more effectively added to some of the compositions of Bach.

The same apparatus was employed in the Church Scene from *Faust* in which Margarita's efforts to pray are stifled by the presence of the voice of Mephistopheles. The production scheme for this scene was worked out by Dr. Herbert Graf who had long been anxious to employ reverberation control in it and to use the voice of Mephistopheles in auditory perspective rather than to have him appear on the stage. We first experimented with the technique in the Metropolitan Opera House. Later, the test scene was produced at Stevens. As we staged it, the song of Margarita coming directly from the singer, the voice of Mephistopheles coming from speakers located in various places at various times, the organ accompaniment coming from speakers backstage, and the orchestral accompaniment, were picked up and played back *via* the reverberation apparatus. The added brilliance and churchlike quality were particularly noticeable in the first five measures of Margarita's song, which is unaccompanied.

The experiment with *Faust* was so successful as to make us confident that the technique involved may be employed to good advantage in opera, in that it serves to establish locale, create mood, and generally carry out the intention of the composer more faithfully than any other means so far attempted.

By far our most interesting set of problems has been concerned with

the control of sound that is used to convey intelligence, as in the case of human speech or song.

Back in 1934 we set out to make the Ghost in *Hamlet* sound like a ghost. We built a voice which was appropriately sepulchral and dubbed it onto an ectoplasmic figure. It created quite an impression. The technique of making the voice consisted in suppressing some of the voice frequencies while emphasizing others. It was not long before the same idea, adapted to radio as a sort of juke-box voice, became part of the standard radio bag of tricks.

It is all very well to control speech by removing some parts and amplifying others, but no matter how cleverly a job is done, one is still hindered by the limitations of the human voice itself. To avoid these limitations one must completely remake the voice. Everyone of us is familiar with, and many have used, the various devices for making speech out of other sounds—the pitch pipe on a rubber tube, the Sonovox, the Vocoder, Professor F. A. Firestone's substitute larynx, and the Voder. They have their uses. Most have many limitations, and none carries conviction unless the spectrum of the sound of which speech is to be made is nearly as wide as the speech spectrum, or unless a visual cue makes the sense of the speech perfectly apparent. These limitations will be illustrated presently.

Despite limitations, there are few elements in dramatic technique that are more intriguing than those involving speech or song by animals or things not endowed with such powers. Shakespeare has Alonso in *The Tempest* say:

Methought the billows spoke, and told me of it;
 and the thunder,
 That deep and dreadful organ-pipe, pronounc'd
 The name of Prosper.

We tried making speech out of wind and thunder last year. It was not so bad when we could get better than 100 db out of the thunder, but it is awful without adequate dynamic range.

We did a little better in an experiment, worked out by Margaret Webster, to see whether the Witches in *Macbeth* could be made into twentieth century demons. These are visible only to Macbeth but cast visible shadows as they moved around the fire. The voices could not carry the show without adequate staging of the visual elements. The voices of three actresses were so rebuilt that their owners would never know them. One was made higher than the

human voice can go, another was given a quality which was a cross between a rock-crusher and a whiskey baritone, and the third was transformed into a basso. For the production, the dialog was played against a background of the scherzo of the Prokofieff's *Concerto in D Major* for violin and orchestra. (Here a recording of the Witches without the background music was played.)

In Eugene O'Neill's *Lazarus Laughed*, an attempt was made to give the laughter the musical quality and dynamic range prescribed for it. The laughter serves in fact as a musical accompaniment to the play and, in addition, motivates action and carries the final scene. We modulated a chord, played on an organ, with human laughter and accomplished variation by the relative amounts of voice and music used, and by the dynamics of the chord.

Inquiry elicited comments that the laughter was appreciated for its novelty, and that it fitted into the production so well as to be accepted without question. I am inclined to feel that we scratched the surface only of what is possible with the play, particularly in the last scene which we used. Scoring all sound in the scene according to a musical pattern, as we did for *The Emperor Jones* and for *Cyrano de Bergerac* in the program of stereophonic recordings, and giving the laughter a varied instrumentation would, I am certain, enhance the effectiveness of the play beyond what has been possible heretofore. Here is the laughter which is a continuous background to part of the scene—sometimes barely audible, sometimes dominant. (A recording was played at this point.)

When Shakespeare put an ass's head on Bottom in *A Midsummer Night's Dream*, he did not have any but mechanical control of Bottom's voice. We thought it would be worth while to see if Bottom could speak with the voice of an ass while wearing the ass's head, and with his own voice the rest of the time. Significant characteristics of an ass's bray seem to be: (1) he uses only vowels; (2) his fundamental frequency range is greater than that of a human voice—he produces his loudest sounds at the high and low ends of that range with little power in the middle; (3) he uses his whole range all the time. Once the Vocoder is set up to produce such a sound, almost anyone talking into it sounds like an ass. You will notice that the ass's voice has a much wider pitch range than the human voice and that enough of the human voice is mixed with that of the ass so that Bottom can at least be recognized. The dubbing was accomplished by reproducing the voice from speakers upstage of the actor, and varying

the output between speakers as the actor moved about the stage. (A recording demonstrating the voice of Bottom was played.)

Since these voices were made for a special theater use, it is not likely that they fulfilled all the requisities for voices similarly conceived but designed for motion picture use. I think they may illustrate, however, what is likely to be in store for us. So, tomorrow, if your alarm clock bell wishes you a cheery good morning, do not rush to the nearest psychiatrist. It may only be the sound department run amok again.

Ed. Note: This paper contains extensive quotations, not otherwise noted, from the author's "Theatrical Uses of the Remade Voice, Subsonics and Reverberation Control," published in *The Journal of the Acoustical Society*, 13, No. 1 (July, 1941), p. 16.

SOUND CONTROL IN THE THEATER COMES OF AGE*

HAROLD BURRIS-MEYER**

Summary.—Some of the implications of the control of the auditory components of a "show" are noted, especially its application to the exhibition of motion pictures.

It has been my privilege to report to this Society from time to time various steps toward the control of the auditory component of the "show." That control is now complete. The purpose of this paper is to note some of the implications of its application to the motion picture.

There is no need to sell, on artistic or technical grounds, the desirability of exercising complete control over everything the audience hears. Good performances without number demand more scope in the control of sound than is possible with conventional apparatus. Apparatus and techniques exist to satisfy these demands. Box office figures confirm the fact that the more flexible the artistic medium, the more the showman prospers. There is danger, however, that when we start to remake the motion picture technically and as an art form after the war, we shall not go far enough in the first step; that we shall limit future developments with stopgap apparatus, thereby missing the greatest opportunity ever to present itself to the industry.

We realize how changed the motion picture would be now if the war had not come along. Many of us know developments made as a part of the war effort which will be applicable to the motion picture when military classification can be removed. With technological progress almost completely stymied, it behooves us to crystallize and agree on our concept of what the post-war motion picture will be like, and to define its objectives to the end that we shall be able to achieve them without a period of technological chaos when the war is over.

Moreover, it is extremely important that we be ready when the time comes. The motion picture is the most important popular art form in the world, and the American motion picture is its most popu-

* Presented at the 1942 Fall Meeting at New York.

** Stevens Institute of Technology, Hoboken, N. J.

lar version. It has had a tremendous effect upon the feelings, habits, hopes, desires and fears of the common man the world over. The impact of the American motion picture when it returns to international circulation will be very great. Its power for good or evil is hard to evaluate. If we make it flexible enough to permit the American artist to do a superlative job, we shall at least have the preferred path to the emotions of all peoples, for many of whom the best elements of the American way of life constitute an ideal.

To make the motion picture what it can and will be, we must enhance the scope of sound control. We have a long way to go. When sound came to the movies, it took time for the idiom to jell, but presently a reasonable integration between the picture, the spoken word and instrumental music was achieved. As matters stand now, sound is still definitely subordinated to the picture. Song and instrumental music are reasonably well reproduced; speech comes over with a tolerable percentage of articulation; effect and background sounds are still, I regret to say, but slight variants of the sound of coal going down a chute. When you listen to the sound-track without the picture, you are well aware of how woefully inadequate it is. This is a deplorable condition. Of the senses that we bring to the theater through which the artist reaches our emotions, the sense of hearing is measurably more effective as a path to the emotions than is vision.

You can do a lot with sound. You can use it as a direct emotional stimulus; you can induce a physiological basis for the generation of emotion. With sound, you can control metabolism; you can increase or decrease muscular energy; you can increase respiration; you can increase or decrease pulse rate; you can control the threshold of sensory perception; you can reduce, delay, allay or increase fatigue. The techniques for accomplishing all these ends exist. It is susceptible of use as a part of an artistic idiom. To the extent permitted by technical limitations, it has been an element in the showman's art since there first were "shows." It still awaits full, conscious exploitation.

Moreover, not only can you do almost anything with sound, but your audience can not escape it. You can shut your eyes if you will, but the sound comes out to get you. I submit that in its progress the art of the motion picture has overlooked or, at best, only vaguely glimpsed its most powerful and, by the same token, its most subtle instrument.

Obviously, if you can make an earnest endeavor to get the most out

of the sound, you have to get it under control and keep it so. This involves:

(1) Control of the intensity of the sound. The dynamic range must be from several db below theater ambient noise level (in a well-designed theater, this level will stay substantially below 40 db), to at least 120 db, which is a perfectly tolerable intensity with tremendous effectiveness when used with discretion. Such a dynamic range must not be accompanied by harmonic distortion at the peaks. It must be possible to record and reproduce sounds with steep wave fronts as found in explosions or in some compositions of Moussorgsky.

(2) Control of the spectrum, which involves the ability to get any auditory signal, including frequencies above and below audible range, on the track and back off it again, to all members of the audience. It means remaking, otherwise electronically reprocessing or synthesizing any sound to give it any predetermined spectrum. It means a theater in which the sound is so distributed that all the frequencies on the track reach everyone in the house at substantially the appropriate levels. Only with such control of spectrum will the drum in *Emperor Jones* have maximum effectiveness, or cause the opera goer to prefer the celluloid to the stage production.

(3) Control of reverberation. This means not only electronically controlled over-all decay time, but control of the *shape* of the decay curve in at least three separate frequency zones. It means theaters with uniform sound decay patterns, with all variations therefrom carried on the film. Then an organ record may sound like a cathedral organ, echoes may be realistic, and a scene in a tent may sound like a scene in a tent.

(4) Control of the apparent direction of the sound. This means having the sound come from any point in a sphere surrounding the audience—from the projection booth, from below the stage, from over the proscenium, from the side wall, or from no place, or from an apparently moving source, *i. e.*, starting in one location and ending in another. It means freeing the sound from the spatial limits of the screen so that the *Angels' Chorus* can be heard from above, or the laughter of Lazarus can envelop the audience.

(5) Control of the apparent distance from which the sound comes. This suggests that the sound must appear to originate from any point or area in a sphere of any size surrounding the audience. It must be able to move along a straight or curved line from any point in any sphere to any point in any other sphere; for example, a mile behind the projection booth to a point within the ear canal of each member of the audience. The control of apparent distance involves, of course, control of direction and control of spectrum.

This is a large order. Yet every element of it has been employed in the theater before audiences who bought their seats to see a "show," most of whom were unaware of the nature or extent of any sound control to be involved, and many of whom do not know to this day that anything they heard had an electronic origin. Moreover, the apparatus now exists by which all of these ends may be accomplished in the motion picture, and there is at least enough technique available to keep the artist from bogging down when first he tries his new wings.

To accomplish the flexibility of sound control which has been outlined here, we must have, first, new apparatus, the nature of which you already know; second, a considerable revision of production technique; and third, new theaters.

The making of the multichannel record requires that the script writer should know what his enhanced medium will do. The stereophonic recordings already made, and the legitimate and operatic productions which have used the Stevens sound control technique, will serve only to point the way, for they have lacked either the visual component or the ubiquitousness which the motion picture provides. The artistic scope of the motion picture is, for the first time in history, literally bounded only by the limits of the artist's imagination.

The multichannel record will demand a revision of current standard practice from script to cutting room. Music, dialog, and other sounds will have to be planned with a view to where they come from, how they move, and what their reverberant characteristics will be. The sound score will have to be more elaborate than that currently employed in the animated cartoon, as those who have made stereophonic records can testify. The work of making the final sound-track from the original will be increased and for a while, until new techniques are mastered, those who make the sound-track will have quite a job keeping up with the artist's fancy.

Then we need new theaters. Theater building has languished for a decade, during which we have almost learned how to build a theater. Many existing theaters are ready for the wreckers; many more are economic liabilities. They will have to be replaced. And though obviously many will be built for productions other than motion pictures, none should be so built that they can not exhibit motion pictures in a manner which is technically simple, artistically satisfactory, and financially sound. The English are already collecting theater plans and specifications against the day when they rebuild after the blitz.

In planning for the control of sound in the theater that is to be, I submit the following fundamental considerations:

(1) Two elements in the manner in which sound is heard determines its acceptability:

(a) percentage of definition, a subjectively determined standard embracing percentage of articulation and blending, and taking cognizance of the direction and efficiency of sound sources;

(b) a vibrant characteristic, embracing the cyclic pattern common to the decay curve and the vibrato, whose characteristics are to be determined by a subjective appraisal of the vibrato rate and decay curve form.

(2) There is an optimum duration for decay of speech which is valid, irrespective of the size of the theater. The decay time for sound must be the same irrespective of the number of people in the theater.

As to music, decay time has been used consciously or unconsciously by the composer as a musical device. It is therefore impossible to make one decay time do for all music. In a theater planned to provide optimum decay time for speech, electronic control of all other sound can be simple and effective, and chamber music, organ music, and opera may sound as the composer intended, irrespective of the size of the theater or the audience.

There will have to be, of course, provision for speaker placement to provide by direct transmission, or reflection for the directional and spatial characteristics the sound must have. You can not make such provision after a theater is built. It must be designed from the start as a part of the acoustic planning, and it will have to be sufficiently uniform and simple to make one type of print satisfactory wherever it is shown.

The objectives I have set are not easy of attainment, to be sure, but they carry the promise of dominance of the world market, and the greatest influence on the most people that any art form has ever had. That is a tremendous responsibility. We shall shirk it if we are satisfied with technological half-measures.

RECENT LABORATORY STUDIES OF OPTICAL REDUCTION PRINTING*

R. O. DREW AND L. T. SACHTLEBEN**

Summary.—This paper reports recent laboratory work which has resulted in marked improvements over previous 16-mm reduction print quality. Improvements in image quality accrue from exposure of the print with ultraviolet light and from the use of reflection reducing coatings on the lens surfaces, while speed variations are reduced by increasing printer speed up to as much as twice normal film speed. These improvements involve only relatively simple changes in commercial reduction printers.

The reduction sound printer¹ was developed because it promised to be the best means of making 16-mm sound-track prints from original 35-mm sound negatives. The earliest method of making such prints involved re-recording, and the unsatisfactory results obtained by that method led to efforts to make the prints by optical reduction. The prints so made showed such marked improvement over the product obtained by re-recording² that the reduction printer was developed into a commercial machine.

The loss of quality in re-recording took place largely in recording the 16-mm sound negative. Efforts to compensate these losses by equalization led to an intolerable distortion. This was later found due to a rectification component originating in the failure of the 16-mm film to resolve the higher frequencies impressed upon it. This failure to resolve the higher frequencies had a double aspect: (a) the wavelengths at any given frequency were only 40 per cent as great on 16-mm film as on 35-mm film, and the loss of resolution due to irradiation in the emulsion was thus greatly aggravated; and (b) the recordings were made with the same slit widths used in 35-mm recording optical systems with a resulting increase of 150 per cent in the ratio of slit width to wavelength at any given frequency. The reduction printer afforded greatly improved 16-mm prints, as well as a more direct method of making them from 35-mm negatives that involved less and simpler equipment.

* Presented at the 1942 Fall Meeting at New York.

** RCA Victor Division of Radio Corporation of America, Indianapolis, Ind.

Since the development of the first successful optical reduction printer, advances in 35-mm sound-recording methods and equipment have been great. Notable among these advances have been exposure of the sound negative and print with ultraviolet light,³ and the introduction of the fine-grain emulsion as a sound-recording medium. Parallel advances have been made in the special technique of record-



FIG. 1. Photomicrograph of 7000-cycle track printed on Eastman 5302 stock, using white light uncoated lenses and white light exposure. Print Density 1.0; Print Gamma 2.0.



FIG. 2. Photomicrograph of 7000-cycle track printed on Eastman 5301 stock, using white light coated lenses and white light exposure. Print Density 1.2; Print Gamma 2.0.



FIG. 3. Photomicrograph of 7000-cycle track printed on Eastman 5301 stock, using white light coated lenses and ultraviolet exposure. Print Density 1.2; Print Gamma 2.0.

ing directly on the slower moving 16-mm film.⁴ These have been successful to the point where 16-mm prints made from the best original 16-mm sound negatives show improved quality over 16-mm prints made from 35-mm original negatives on an unimproved optical reduction printer. For various reasons it has remained until the present time to show the extent to which the product of the reduction printer may be improved by adoption of means made available since these printers were built.

In studying the possibilities of improving reduction prints, the following desirable advances were made the objective:

- (1) Increased density in the black areas of the print.
- (2) Reduced fog density in the clear areas of the print.
- (3) Extended frequency range and reduced distortion.
- (4) Reduced image grain.
- (5) Reduced "wows" in the prints.

Proved experience in the 35-mm sound-recording field suggested the redesign of the reduction printing optical system for ultraviolet light, and the ultraviolet exposure of the reduction print, as a most promising step in the printer's improvement—and this step was taken. The presence of the large number of glass-to-air surfaces, characteristic of the optical trains of reduction printers, suggested that the newly developed lens coating process should be employed to reduce the stray light resulting from reflections⁵ at those surfaces. This was also tried. Prints were made on the new fine-grain emulsions with both white and ultraviolet light to learn what improvements might result from the use of such emulsions. Finally an effort was made to learn if the wows introduced into the reduction prints by the printer itself could be reduced by an increase in the speed of the printer.

The laboratory studies made along these lines, and here reported, indicate that reduction printers can be greatly improved in all of the above tabulated respects.

OPTICAL IMPROVEMENTS

An optical reduction printer was obtained from a commercial laboratory. It was put into optimum adjustment, and a series of prints were made for each of the conditions tabulated in Table I below. Thirty-five-millimeter ultraviolet exposed speech and music

TABLE I
Printing Conditions

Condition	Type of Optics	Lens Surface Condition	Quality of Light Used	Eastman Emulsion No.	Gamma
1	White light	Uncoated	White	5302	2
2	White light	Coated	White	5301	2
3	White light	Coated	Ultraviolet	5301	2
4	Ultraviolet	Coated	Ultraviolet	5301	2
5	White light	Coated	White	5302	2.5
6	Ultraviolet	Coated	Ultraviolet	5302	2.5

negatives were printed for listening tests to learn which were the best negative and print densities to use. Frequency prints were made under the conditions so determined, and their response measured.

The speech and music prints made under conditions 2 through 6 were carefully listened to by a group of three observers, who con-



FIG. 4. Photomicrograph of 7000-cycle track printed on Eastman 5301 stock, using ultraviolet coated lenses and ultraviolet exposure. Print Density 1.2; Print Gamma 2.0.



FIG. 5. Photomicrograph of 7000-cycle track printed on Eastman 5302 stock, using white light coated lenses and white light exposure. Print Density 1.2; Print Gamma 2.5.



FIG. 6. Photomicrograph of 7000-cycle track printed on Eastman 5302 stock, using ultraviolet coated lenses and ultraviolet exposure. Print Density 1.2; Print Gamma 2.5.

cluded that in all cases the best print density was about 1.2. Cross-modulation tests⁶ were made which helped to substantiate this conclusion. In the case of the print made under condition 6, it was found that the density could be increased to 1.5 without noticeable loss of quality. The corresponding 35-mm negative densities were in the commercial range of 1.9 to 2.0.

Figs. 1 through 6 are photomicrographs of 16-mm variable-area, bilateral, 7000-cycle prints made by optical reduction at a density of

1.2 (for Fig. 1, the density is 1.0) under the correspondingly numbered conditions of Table I. These photomicrographs show that when using white light and the original white light optics (Fig. 1) of the optical reduction printer under study, the print resolution is improved by coating the lenses (Fig. 2), and still further improved by the introduction of an ultraviolet filter (Fig. 3), the improvements being of about the same order of magnitude in each case. The change to coated lenses designed especially for ultraviolet light (Fig. 4) increased resolution another step. The photomicrograph of Fig. 5

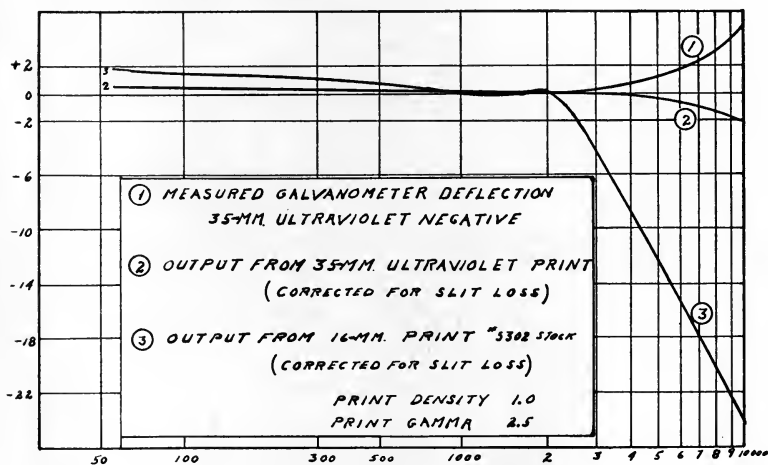


FIG. 7. Reproduced frequency characteristics of an optical reduction print made on Eastman 5302 stock with white light uncoated lenses and white light exposure.

shows the resolution obtained when printing on Eastman 5302 stock with white light using a coated white light optical system, to be lower than when printing on Eastman 5301 stock with ultraviolet light using a coated ultraviolet optical system. The photomicrograph of Fig. 6 shows a print made on Eastman 5302 stock with ultraviolet light using a coated ultraviolet optical system and represents the best reduction print quality obtained during the course of the experiments.

The result of coating the lenses was an increase in resolution due to reduction of stray light, and most notably a reduction of clear area density from 0.08 to 0.02. At the same time the maximum satis-

factory print density has been raised from about 1.0 to 1.2. As a result, noise has been reduced and signal level increased.

Table II tabulates in the order of decreasing print quality, the ratings based on listening tests of the prints made under conditions of Table I.

Print Quality Rating	Condition (See Table I)
1st	6
2nd	4
3rd	3
4th	5
5th	2

Conclusions drawn from microscopic examination of the prints were in exact agreement with these ratings.

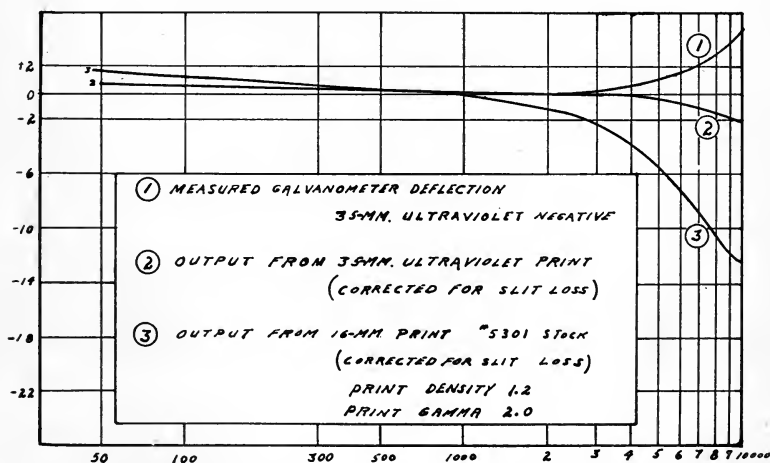


FIG. 8. Reproduced frequency characteristics of an optical reduction print made on Eastman 5301, with ultraviolet coated lenses and ultraviolet exposure.

The audible quality difference between any two adjacent prints in the above tabulation was at least a whole order of magnitude and was in no case a small or doubtful difference.

Figs. 7 through 9 are, respectively, response curves of prints made from ultraviolet exposed negatives before improvement of the printer (condition 1), and of the best prints made on the Eastman 5301 and

5302 emulsions from ultraviolet negatives using coated ultraviolet printer lenses and ultraviolet light (conditions 4 and 6). Accompanying each curve are curves showing the equalization in the original 35-mm negative and the measured response of the 35-mm print made from it for comparison.

Distortion measurements for several frequencies were made up to 3000 cycles on prints made under conditions 4 and 6 of Table I, and the total distortion was found to be not greater than 4 per cent.

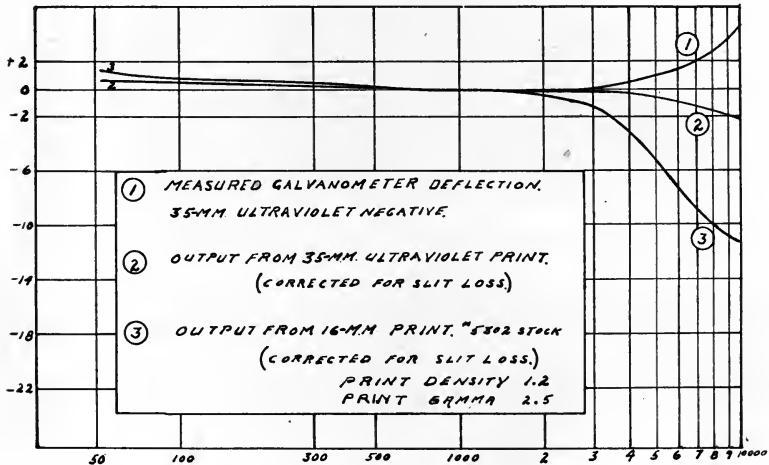


FIG. 9. Reproduced frequency characteristics of an optical reduction print made on Eastman 5302, with ultraviolet coated lenses and ultraviolet exposure.

FILTERING IMPROVEMENTS

Coincident with the experiments directed toward improving the resolution of the reduction prints, efforts were made to reduce the frequency variations or wows introduced into them by the printer itself. Theoretical studies have shown that beyond a certain very low disturbance frequency, the filtering action of film-moving mechanisms is improved by increasing the frequency of the disturbance.⁷ This applies to almost all driving systems where filtering of any kind is employed. Accordingly, tests were made at several increased printer speeds, up to twice the normal speed or 72 16-mm ft per minute. It was found that filtering improved with each increase of speed.

Figs. 10 and 11 are "wowgrams" of reduction prints made at 36 and 72 16-mm ft per minute, respectively. The measured wow was 0.7 per cent at 36 ft per minute, and 0.3 per cent at 72 ft per minute. These figures express the wow content in terms of peak-to-peak values; that is, the wow content is the difference between the maximum and minimum speeds attained during the period covered by the oscillogram expressed as a per cent of the average speed. The rms figure for the indicated flutter would be considerably less than half the above values.

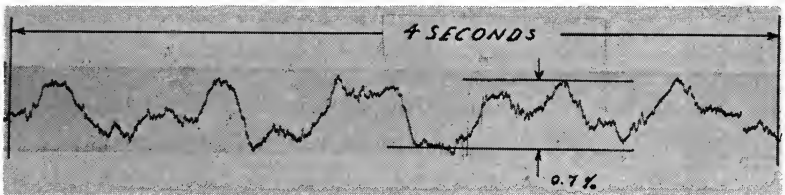


FIG. 10. Oscillogram showing speed variation in print made at 36 ft per min.

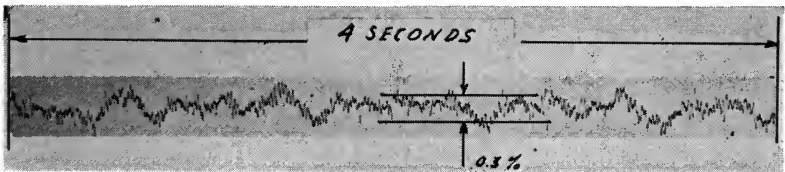


FIG. 11. Oscillogram showing speed variation in print made at 72 ft per min.

CONCLUSIONS

Early-type optical reduction printers can be made to give greatly improved performance by making relatively simple changes in them, as follows:

- (1) Replacement of white light lenses by ultraviolet lenses.
- (2) Coating all glass-air surfaces to reduce reflections.
- (3) Introduction of an ultraviolet filter in the optical train.
- (4) Increase of the printer speed up to 72 16-mm ft per min.

As a result of such changes the quality improvements realized in the case of the prints made in our tests, were:

- (1) Reduction of clear density from 0.08 to 0.02.
- (2) Increase of opaque density from 1.0 to 1.2.

- (3) Reduction of loss at 7000 cycles from 18.0 db to 8.4 db.
- (4) Limitation of total distortion at frequencies as measured to 4 per cent or less.
- (5) Reduction of speed variations or wow to less than half.

An increase in the printer speed from 36 to 72 ft per minute for the 16-mm film will result in a proportionate increase in the number of prints produced by the machine.

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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 or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y., at prevailing rates.

American Cinematographer

24 (Sept., 1943), No. 9

Mitchell 35-Mm Single System Sound Camera
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E. J. TIFFANY

24 (Oct., 1943), No. 10

The Evolution of Transparency Process Photography (p. 359)

F. EDOUART

The New Mitchell Background Projector
(p. 363)

E. J. TIFFANY

Third-Dimensional Films in Soviet Union
(p. 366)

M. KALATOZOV

Educational Screen

22 (Sept., 1943), No. 7

OWI's 16-Mm Motion Picture Program, July, 1942-June, 1943 (p. 233)

P. C. REED

Visual Aids in Cleveland Schools (p. 236)

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Split-Second Seeing (p. 239)

S. R. ELLIS

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M. TERRELL

International Projectionist

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A Complete Study on the Prevention of Film Damage (p. 16)

H. B. SELLWOOD

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Analysis of a Preview Theater System (p. 10)

L. CHADBOURNE

Film Distortions: Their Effect Upon Projection Quality (p. 12)

E. K. CARVER, R. H. TALBOT,
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| Stand-by Features for Sound Systems (p. 7) | L. CHADBOURNE |
| Effect of High-Intensity Arcs Upon 35-Mm
Film Projection (p. 10) | E. K. CARVER, R. H. TALBOT,
AND H. A. LOOMIS |
| Fuses in the Projection Room (p. 16) | C. D. WELCH |
| 18 (Oct., 1943), No. 10 | |
| Selection and Maintenance of Switches (p. 7) | H. B. SELLWOOD |
| Television Today, I—Electronics Devices
(p. 10) | J. FRANK, JR. |
| Effect of High-Intensity Arcs Upon 35-Mm
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| The Light on Your Screen (p. 86) | C. E. SHULTZ |
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SOCIETY ANNOUNCEMENTS**OFFICERS, GOVERNORS, AND MANAGERS, FOR 1944**

As a result of the elections held recently, the following is a list of Officers and Governors of the Society for the term beginning January 1, 1944:

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- * *Executive Vice-President:* LOREN L. RYDER
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- * JOSEPH H. SPRAY
- * WILLIAM A. MUELLER
- * H. W. REMERSHIED
- ** WALLACE V. WOLFE

* Term expires December 31, 1944.

** Term expires December 31, 1945.

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- * WALLACE V. WOLFE

We regret to announce that word has just been received of the death of Frank F. Renwick, Fellow of the Society, in England on August 14, 1943.

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS



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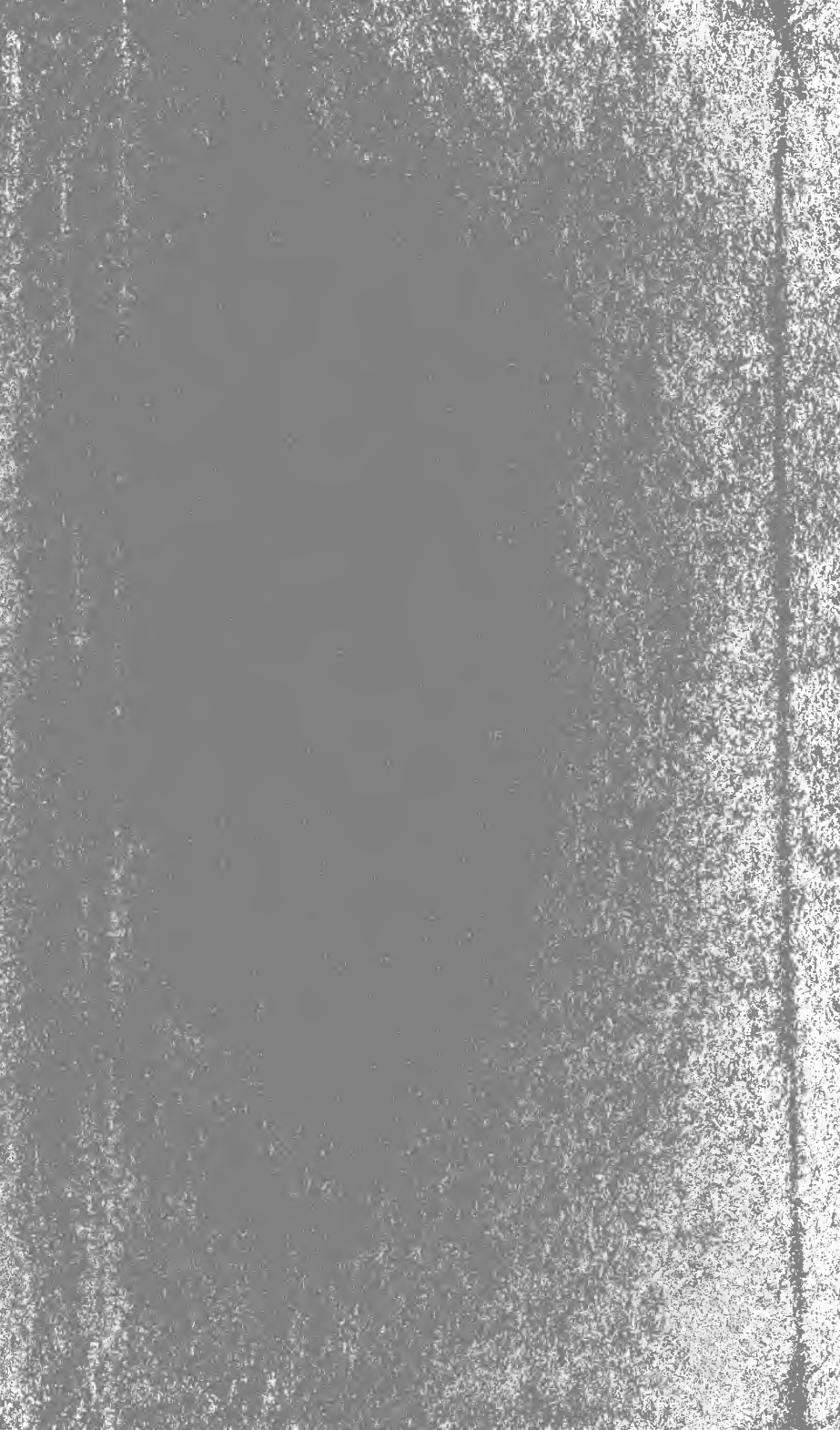
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