B. E. STECHBART

5 7 4

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 JULY, 1945 No. 1

CONTENTS

Indexes to the semi-annual volumes of the JOURNAL are published in the June and December issues. The contents are also indexed in the *Industrial Arts Index* available in public libraries.

JOURNAL

OF THE

SOCIETY of MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA • NEW YORK 1, N.Y. • TEL. PENN. 6 0620

Subscription to nonmembers, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscription or single copies of 15 per cent is allowed to accredited agencies. Order from the Society at address above.
Published monthly at Easton, Pa., by the Society of Motion Picture Engineers, Inc.
Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, Hotel Pennsylvania, New York 1, N. Y.
Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 JULY, 1945 No. 1

COMPARISON OF VARIABLE-AREA SOUND RECORDING FILMS*

DOROTHY O'DEA**

***Summary.**—This paper describes the test results obtained by comparing the new Eastman 1372 film with those in current use. Our tests indicate that this film has characteristics superior to the Eastman films now in use for variable-area sound recording, particularly with respect to density speed, processing tolerances, and requirements for direct positive.*

A new film, Eastman Fine-Grain Sound Recording Film, type *1372*, has been placed on the market for use in variable-area sound recording. Our tests show that the characteristics of this film are superior to the Eastman films now in use for this purpose.

The commercial value of a film can be indicated by exposure tests, sensitometric data, high-frequency attenuation measurements, and cross-modulation tests.[1] Other practical considerations which are of importance, such as aging, durability, freedom from fog, and uniformity, can only be found after extensive use in the field, and are not within the scope of this paper.

The cross-modulation tests, in brief, consist in making recordings of 1000 cycles and 9000 cycles modulated by 400 cycles exposed with a wide range of lamp currents. The high-frequency attenuation measurements are made by recording 9000 cycles at the same time. This negative is developed and then printed at different print densities to obtain a family of curves. The 1000-cycle recording serves as a reference level, and the output of the 9000 cycles indicates the loss at high frequencies. The 9000 cycles modulated by 400 cycles are reproduced through a 400-cycle band pass filter, and the combination of negative and print density which cancels the image spread will

* Presented Oct. 17, 1944, at the Technical Conference in New York.

** RCA Victor Division, Radio Corporation of America, Hollywood.

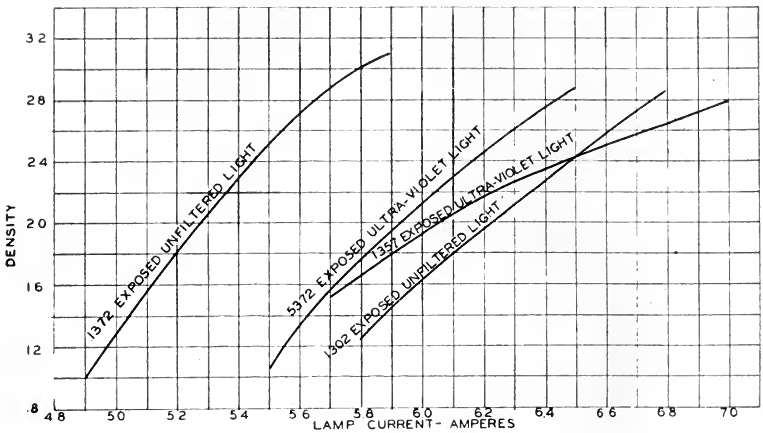


Fig. 1. Exposure tests, lamp current versus density. Developed in variable-area negative developer.

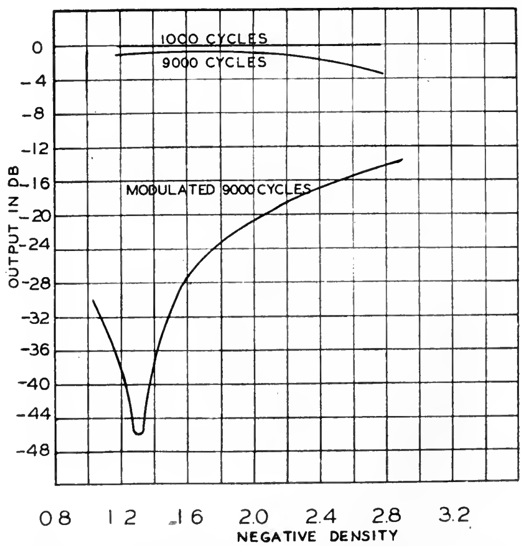


Fig. 2. Processing characteristics, *5372*. Negative exposed with ultraviolet light and developed in variable-area negative developer.

give minimum output, as the 400-cycle component is only present when the printer, exposure, and developing conditions are not balanced and the average transmission changes at a rate of 400 cycles. It has been found in past experience that cancellation of 30 db or more is satisfactory.

To assure accurate results, the equipment employed for this series of tests was first carefully aligned. The recorder was not refocused between unfiltered light and ultraviolet light recordings. However, when it was learned that the *1372* is 0.0003 in. less thick than other variable-area sound recording stocks, the recorder was refocused for the new film. A negative and prints were made which compare closely with those made before refocusing.

Comparisons were made between the new film, *1372*, and the *1357* and *1302* films. The *1357* has been used successfully as a variable-area sound negative material since 1936, and the *1302* has been used as a negative and print stock. The *1372*-type emulsion which was used for our tests was on acetate base cut to 35-mm width for test samples, and therefore bore the code number *5372*. When the regular *1372* on nitrate base was available, more tests were made to check the new stock and the only difference found was a drop in the negative balance density from 1.3 to 1.2. The *1372* film has a blue-gray base with a density of approximately 0.24 (read on a visual densitometer), which is a lower density than the *5372*. All negative density readings mentioned in this paper include the base density. When using pieces of "fixed out" film in the optical path of the reproducer, the loss in output due to the base density of the film is 2 db for the *1372* as compared with 0.5 db for the *1302*. It is probable that the discrepancy between the density measurements and the loss in level is caused by the color characteristic of the base and the spectral sensitivity of the measuring equipment. One of the studios reports no noticeable difference in level when splicing the *1372* with a clear base stock such as *1302* and using them as print stocks for dailies. In general, it is planned to use only *1372* for dailies when the change-over to the new stock is complete in a studio, in which case there should not be any difficulty.

The high-density speed of the *1372* film makes it possible to expose the negative with ultraviolet light at reasonable values of lamp current, as shown in Fig. 1. A Corning *597* filter 3-mm thick was placed in the optical path of the recorder for the *1372* and *1357* negatives. The *1302* film was exposed with unfiltered light.

Prints which were to be developed in the release print developer were exposed with unfiltered light, and prints which were to be developed in the variable-area negative developer were exposed with

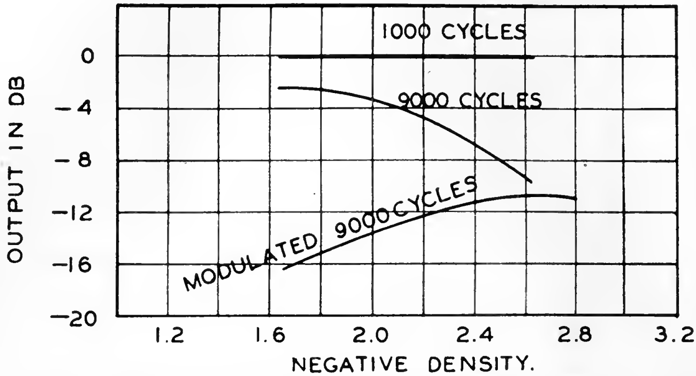


FIG. 3. Processing characteristics, *1357*. Negative exposed with ultraviolet light and developed in variable-area negative developer.

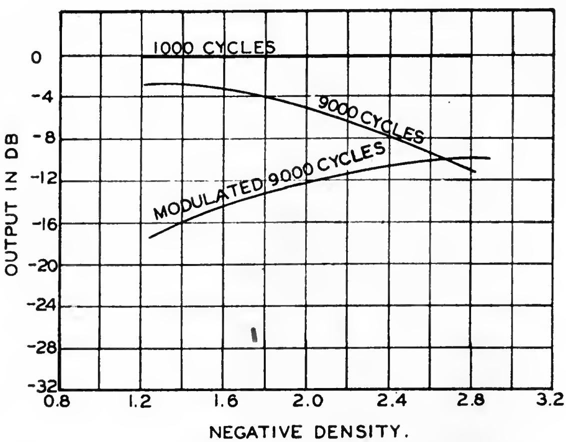


FIG. 4. Processing characteristics, *1302*. Negative exposed with unfiltered light and developed in variable-area negative developer.

ultraviolet light. All prints were made on *1302* stock and printed on a modified Bell and Howell printer.

The variable-area negative developer mentioned above has the characteristics of higher contrast, higher density speed, and higher shoulder break than the release print developer. The release print, or positive, developer fills the contrast requirement for picture prints. When the composite release print is developed in this solution, the lower contrast of this developer is not ideal for variable-area sound tracks, and the lack of sharpness introduced by this condition must be compensated for by the use of a high negative density.

The gamma of the *1372* is appreciably higher than the *1357* and slightly higher than the *1302*. When exposed with unfiltered light and developed in the variable-area negative developer, the gamma is approximately 3.6 as compared with 2.9 for the *1357* and 3.5 for the *1302*. When exposed with ultraviolet light and developed under the same conditions, the *1372* gamma is 2.95 as compared with the *1357* gamma of 1.95 and *1302* gamma of 2.2. Detailed sensitometric data are covered in a paper entitled "Two New Fine-Grain Sound Recording Films" by R. M. Corbin, N. L. Simmons, and D. E. Hyndman.*

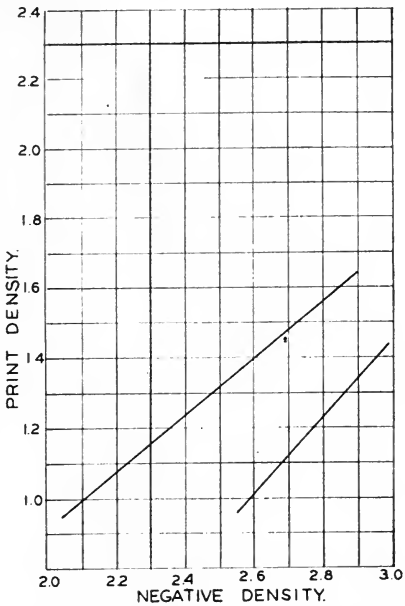


FIG. 5. Processing tolerances, *5372*. Negative exposed with ultraviolet light and developed in variable-area negative developer. Prints developed in positive developer.

An outstanding characteristic of this *1372* film, which is evident in Fig. 2, is its ability to be used as a direct positive material. This negative developed normally has very good high-frequency response, and the negative balance density, or density at which the image spread is minimum, occurs at the reasonably high density of 1.2. Previous films have had negative balance densities no higher than 0.8, which resulted in low output and high noise level. This improvement is noticeable by comparison with the *1357* and *1302*, as illustrated in Figs. 3 and 4. It is hoped that the advantages of the direct posi-

* To be published in the JOURNAL.

tive method of recording for special purposes can be fully realized now that a suitable film is available.

Families of prints made from negatives on these 3 films may be compared to illustrate the differences which will be found in practice. Prints were made in the release print developer, and summary curves from these families are shown in Figs. 5, 6, and 7. These summary curves are made from the cross-modulation tests by plotting the negative densities which will give at least 30 db cancellation for different

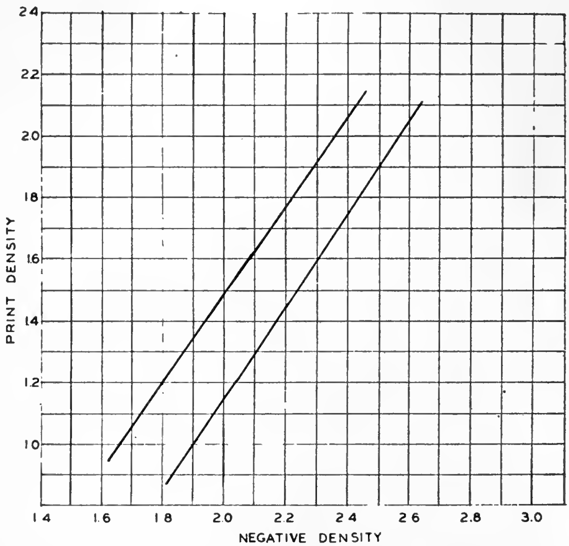


FIG. 6. Processing tolerances, *1357*. Negative exposed with ultraviolet light and developed in variable-area negative developer. Prints developed in positive developer.

values of print density. Although the cancellation would be equally good for almost any combination of negative and print density on these curves, it is necessary to select a print density of 1.3 or higher and use the negative density which corresponds. This value of 1.3 or higher is limited in the low density direction by the necessity of securing sufficient output and freedom from noise. It is limited in the high density direction by the high-frequency attenuation and negative exposure available.

In the case of the *1372*, the negative density which gives the best

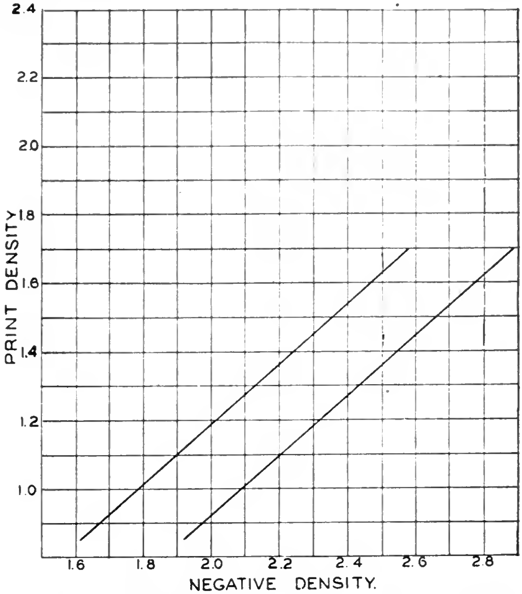


FIG. 7. Processing tolerances, *1302*. Negative exposed with unfiltered light and developed in variable-area negative developer. Prints developed in positive developer.

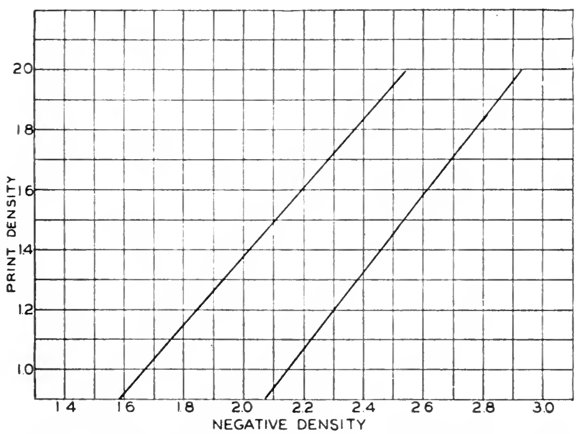


FIG. 8. Processing tolerances, *5372*. Negative exposed with ultraviolet light. Negative and prints developed in variable-area negative developer.

cancellation at a normal print density is approximately 2.7. It will be noted from the summary curves that the tolerance in negative density which can be allowed for any set values of tolerance in print density is much greater for the *1372* than for the other 2 films.

The high-frequency response of the *1372* is slightly better than that of the *1357* or *1302*. Under normal conditions, that is, using the *1357* as a negative developed in the negative developer and printed on *1302* stock developed in the positive developer, the attenuation at 9000 cycles has been approximately 5 db. When the *1372* is used under the same conditions, the 9000-cycle attenuation is only 3 db.

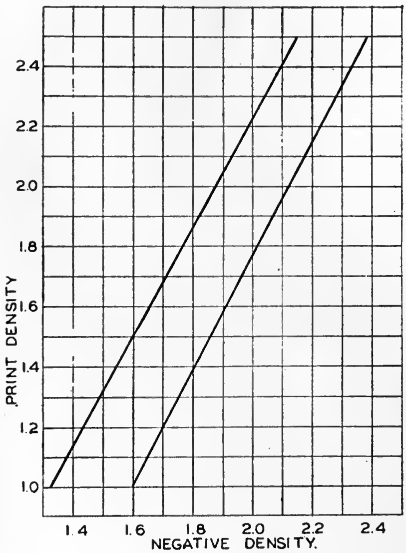


Fig. 9. Processing tolerances, *1357*. Negative exposed with ultraviolet light. Negative and prints developed in varible-area negative developer.

In order to get the best quality on prints from the original negative made for rerecording or "dubbing" purposes, they are developed in the variable-area negative developer. Families of prints were made under these conditions. From a comparison of these 3 curves, 8, 9, and 10, it will be noted that there is also more tolerance in the *1372*. Under dubbing print conditions an improvement of 2 db in the high-frequency response is noted similar to that found under release print conditions. It is obvious that the use of the *1372* as the print stock would further widen the cross-modulation tolerances and improve the high-frequency response.

Owing to the high resolving power of this new film it was considered possible that the negative could be developed satisfactorily in the print-type developer and still retain satisfactory sound quality. It was found, however, that the negative density tolerances were very narrow. While it is possible to develop both negative and print in the print developer and obtain good quality, it is not advisable to do so in production, as all phases of recording and processing would have to be controlled within impractical limits to obtain consistently good results.

Referring again to Fig. 1, this film exposed with ultraviolet light has a higher density speed than the *1302* exposed with unfiltered light. A *1372* negative was also made with unfiltered light and developed in the negative developer. It compares favorably with the *1372* exposed with ultraviolet light and has the advantage of saving approximately 0.7 amp in lamp current.

It was considered desirable to investigate the combination of the 2 previous tests, that is, exposing the *1372* film with unfiltered light and developing the negative in the print-type developer. Prints from this negative show the same narrow tolerances found on the prints from the *1372* exposed with ultraviolet light and developed in the print-type developer.

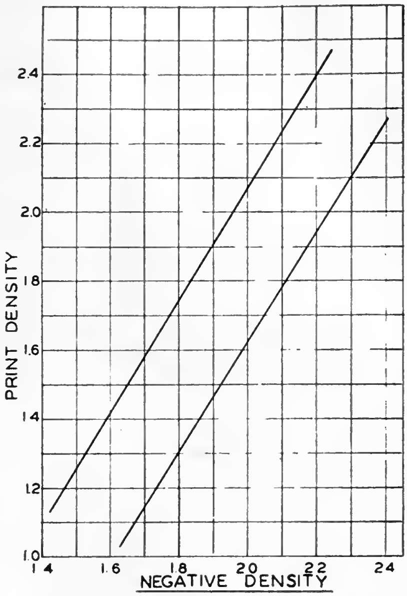


FIG. 10. Processing tolerances, *1302*. Negative exposed with unfiltered light. Negative and prints developed in variable-area negative developer.

The writer wishes to take this opportunity to express her appreciation for the generous help provided by R. V. McKie.

REFERENCE

[1] BAKER, J. O., AND ROBINSON, D. H.: "Modulated High-Frequency Recording as a Means of Determining Conditions for Optimal Processing," *J. Soc. Mot. Pict. Eng.*, **XXX**, 1 (Jan., 1938), p. 3.

METHOD FOR MEASUREMENT OF BRIGHTNESS OF CARBON ARCS*

M. T. JONES, R. J. ZAVESKY, AND W. W. LOZIER**

Summary.—*The brightness, or candlepower per unit area, of a light source is an important determinant of the intensity in a projected light beam. A method is described for measuring brightness of carbon arcs by determining the light intensity on a projected image of the source. The principles of the system and the equipment used for the measurement are discussed.*

The significance of source brightness, or candlepower per unit area, in light projection systems such as are used in the motion picture industry has been discussed in numerous instances.[1] Briefly, the light intensity on the motion picture screen increases with an increase in source brightness if all other factors remain constant.

The purpose of this paper is to describe the technique used in our laboratories to measure the brightness of carbon arc sources. Basically the method involves the measurement of the light intensity on a projected image of the source.

Fundamental Considerations.—In Fig. 1 is shown a sketch in which the letter B represents a point on the crater of a positive carbon with a brightness B expressed in candlepower per unit area, and the letter E refers to the light intensity at the corresponding point on the image, expressed in lumens incident per unit area. The angle α indicated in the sketch is the half angle of the cone of light received through the lens from B, while θ is the half angle of the cone of light collected by the lens from B.

The mathematical expression

$$E = \pi B \sin^2 \alpha \qquad (1)$$

relates the light intensity E to the brightness B, the constant π, and the angle α. This equation holds when the source obeys Lambert's cosine law of emission and when the lens used to form the image ful-

---

* Presented Oct. 16, 1944, at the Technical Conference in New York.

** National Carbon Company, Inc., Fostoria, Ohio.

fills the sine condition. Since these fundamental relationships and conditions have been thoroughly explained elsewhere,[2] no further elaboration will be given to them here.

According to the laws of optics,[2] the magnification of the crater at the image is given as

$$M = \frac{\sin \theta}{\sin \alpha}$$

where M signifies linear magnification. If θ and α are small enough then for all practical purposes

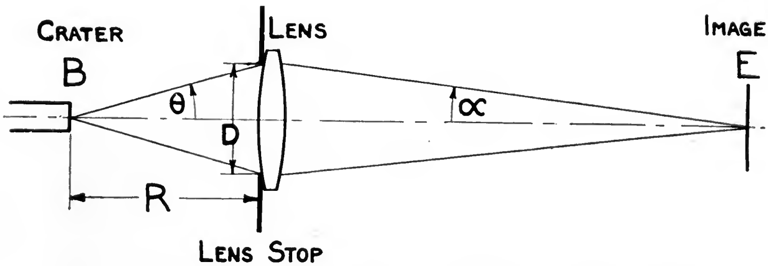


FIG. 1. Sketch of optical system for brightness determination.

$$\sin \theta = \theta$$
$$\text{and } \sin \alpha = \alpha$$

θ may also be expressed as

$$\theta = D/2R$$

where D is the diameter of the lens stop and R is the distance from the lens stop to the crater as illustrated in Fig. 1. Therefore the fundamental expression

$$E = \pi B \sin^2 \alpha$$

may be rewritten as

$$B = EM^2 \times \frac{4R^2}{\pi D^2} \quad (2)$$

Eq (2) does not take into consideration lens transmission which is neglected in the basic relationship expressed by Eq (1). If E is measured in foot-candles and distances are expressed in feet, then Eq (2) will result in a value of B in candlepower per sq ft. In order to include the lens transmission factor and to express B in the more generally used term of candlepower per sq millimeter, the following expression results from Eq (2):

$$B = E \times \frac{M^2}{T} \times \frac{4R^2}{\pi D^2} \times \frac{1}{(12 \times 25.4)^2} \qquad (3)$$

where B = candlepower per sq millimeter of source.
E = foot-candles intensity on image.
M = linear magnification.
T = lens transmission.
R = distance lens stop to crater.
D = diameter of stop in contact with lens.

$\frac{1}{(12 \times 25.4)^2}$ = constant to convert brightness from candlepower per sq ft to candlepower per sq millimeter.

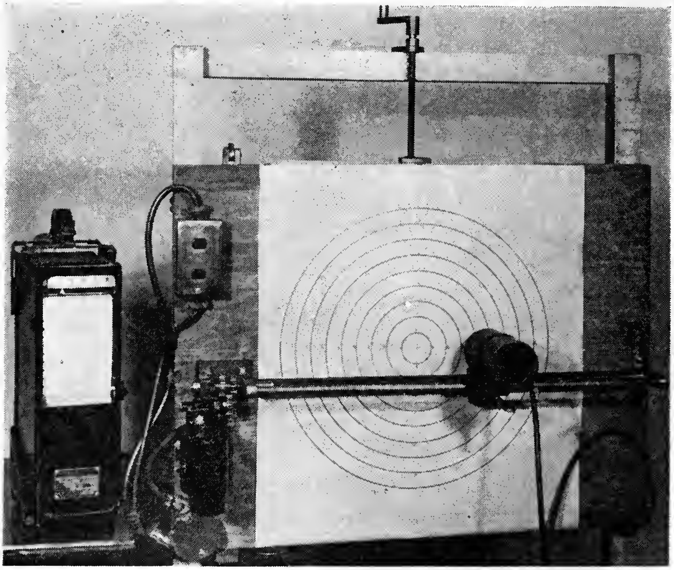


FIG. 2. View of photocell, recorder, and mechanism for measuring brightness.

It can be seen from Eq (3) that if the quantities M—the magnification, T—lens transmission, R—the crater to lens distance, and D—the diameter of the lens stop, are known, the determination of brightness resolves itself into a measurement of light intensity in foot-candles on the projected image of the positive carbon crater.

Method and Equipment for Brightness Measurement.—The fundamental optical system used in measuring brightness is as illustrated in Fig. 1. The carbon arc sources and the optical system fulfill Lambert's law and the sine condition sufficiently well over the 2 or 3 degrees total collecting angle involved to meet the fundamental requirements of Eq (1).

The light intensity in foot-candles on the image is measured with a photocell having a spectral response approximating the eye sensitivity curve. A small lens of approximately 7 in. focal length is used to project the crater image. The magnification is calculated from the

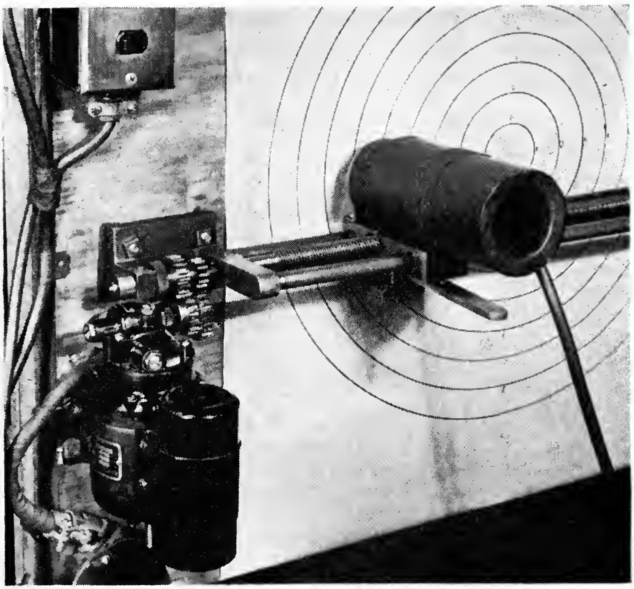


FIG. 3. Close-up of motor and driving mechanism for photocell.

ratio of the image and object distances, and is also verified by projecting the image of an accurately gauged piece of metal. The lens transmission is determined and approximates 0.92. The lens to crater distance and the diameter of the stop in contact with the lens are also measured. All these determinations result in the specification of E, M, T, R, and D in Eq (3).

Fig. 2 shows the complete assembly developed by our laboratory for measuring brightness. This includes photocell, recording meter, and mechanical arrangements.

It has been found convenient to use a magnification of 25.4:1 since this makes one inch at the image equivalent to one millimeter at the source. The photocell is masked to a 1/2-in. diameter which corresponds to 1/2-mm diameter at the crater. The photocell output is recorded with a microammeter calibrated in foot-candles, and a value of *D*, the diameter of the lens stop, is so chosen that the photocell output recorded in microamperes can be multiplied by a round number such as 100 or 200 to read directly in candlepower per sq millimeter. Suitable corrections are made for any departure from linearity in the foot-candle versus microammeter calibration.

Although the fundamental Eq (1) upon which the method of measuring brightness depends is defined only for points on the axis of the system, the angles involved in measuring brightness for off-axial

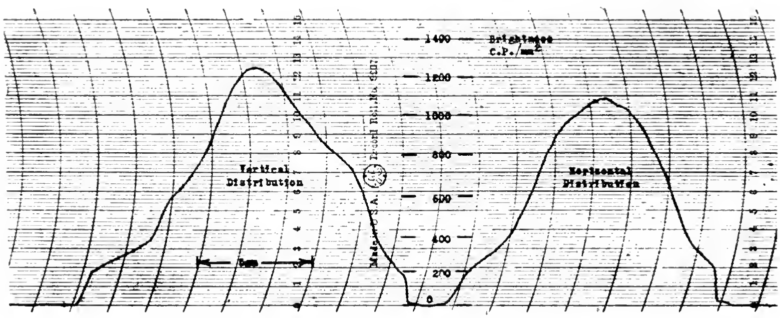


FIG. 4. Record of brightness distribution across positive carbon crater.

positions are so small that corrections can be neglected. Accordingly the distribution of brightness accross the crater is determined by passing the photocell through the crater image. The photocell is carried across the projected image by a synchronous motor-driven screw. Fig. 3 shows the arrangement of the motor and driving mechanism. The output of the photocell is recorded on a chart driven by another synchronous motor.

The brightness measuring unit has a number of convenient features. The image board on which the photocell and driving mechanism are mounted can be rotated through any angle between 0 and 90 degrees so that the crater image can be traversed by the photocell to give a brightness distribution across the crater in a horizontal, vertical, or any intermediate direction. The frame on which the image board is mounted is on a carriage to permit easy movement and also to facilitate horizontal alignment of the image on the board. A crank and screw arrangement makes it possible to adjust the vertical alignment of the image on the board. The motor driving the photocell is reversible and by stopping the motor the photocell can be used to record brightness versus time at any part of the crater image. The photocell can be disengaged from the screw drive very quickly by means of a simple clutch to permit rapid positioning of the photocell on the image board.

Since the photocell is carried across the image by a synchronous motor-driven screw and the recording microammeter chart is driven by a synchronous motor, various positions on the chart are directly related and measurable in terms of position on the source. A chart of crater brightness distribution as recorded by this apparatus is illustrated in Fig. 4. Since the height of the curve is representative of candlepower per sq millimeter and the chart travel is a measure of crater dimensions, it is possible to use such curves to determine the crater candlepower by graphical integration.

The mechanism and method described have been valuable, dependable, and rapid for making the important measurement of brightness. The fundamentals of the method are based on well-known and well-described principles. The mechanism employed to apply these principles was developed to provide a laboratory tool simple and convenient to use.

REFERENCES

[1] COOK, A. A.: "A Review of Projector and Screen Characteristics and Their Effects Upon Screen Brightness," *J. Soc. Mot. Pict. Eng.*, **XXVI**, 5 (May, 1936), p. 522.

[2] HARDY, A. C., AND PERRIN, F. H.: "The Principles of Optics," McGraw-Hill Book Co., Inc. (New York), 1932, ch. XIX, pp. 409–416.

FREQUENCY ALLOCATIONS FOR THEATER TELEVISION

Ed. Note.—*On May 25, 1945, the Federal Communications Commission issued an official report allocating frequencies to the various nongovernmental radio services from 25,000 to 44,000 and from 108,000 to 30,000,000 kilocycles. Subsequently the FCC also issued a final report on allocations to the various nongovernmental radio services from 44,000 to 108,000 kilocycles.*

The Society of Motion Picture Engineers, through its representative, Paul J. Larsen, submitted recommendations for allocations of frequencies for a national theater television service at different hearings held before the FCC, which have been reported in previous issues of the Journal. [***44***, *2 (Feb., 1945), pp. 105–137;* ***44***, *4 (Apr., 1945), pp. 263–274.*]

The FCC granted allocations of frequencies for experimentation of theater television on a "parity of opportunity" basis with television broadcasting. The following tabulation compares the SMPE requests with the proposed and final allocations granted by the Commission:

TABULATION OF ALLOCATION OF FREQUENCIES FOR THEATER TELEVISION

	SMPE Request		FCC Proposed, Jan. 15, 1945		FCC Granted May 25, 1945	
	Band From To	Total MC	Band From To	Total MC	Band From To	Total MC
	600–760	160	*480–920	440	480–920*	440
	860–1000	140				
					1325–1375	50
	1900–2200	300	1900–2300	400	1750–2100	350
					2450–2700	250
	3900–4200	300	3900–4550	650	3900–4400	500
	5700–6300	600	5750–7050	1300	5650–7050	1400
Total below 10,000 Megacycles		1500		2790		2990
			10,500–13,000	2500	10,500–13,000	2500
			16,000–18,000	2000	16,000–18,000	2000
			26,000–30,000	4000	26,000–30,000	4000
Total above 1000 Megacycles		0		8500		8500
Total Megacycles		1500		11,290		11,490

* Experimental to be discontinued when needed for broadcast service.

The allocations of frequencies for experimental theater television granted by the FCC now permit the motion picture industry to proceed with plans for this new service by filing of applications in specific portions of the frequency spectrum.

Excerpts from the final FCC report are given here to complete the published record of SMPE activities in this matter.

EXCERPTS FROM REPORT BY FEDERAL COMMUNICATIONS COMMISSION ON PROPOSED ALLOCATIONS FROM 25,000 KILOCYCLES TO 30,000,000 KILOCYCLES* (DOCKET NO. 6651)

INTRODUCTION

This report contains the Federal Communications Commission's allocations to the various non-governmental radio services from 25,000 to 44,000 and 108,000 to 30,000,000 kilocycles. No final allocations are being made at this time for the portion of the spectrum between 44 and 108 megacycles. Instead three different alternative allocations are set forth...and further measurements and tests will be conducted during the summer in order to aid the Commission in deciding the best allocation for this portion of the spectrum.

This report should be read in conjunction with the proposed report of allocations above 25,000 kilocycles, dated January 15, 1945. That proposed report is adopted as the final report of the Commission except as modified or brought up to date by this report.

It is contemplated in the near future to issue a proposed report for allocations below 25,000 kilocycles and as soon thereafter as possible a final report for such allocations. It is the Commission's intention thereafter to issue one final report bringing together in one place all of the material in the various proposed reports and final reports.

PART I

DESCRIPTION OF THE COMMISSION'S PROCEEDINGS AND STATEMENT OF ITS ALLOCATION

INTRODUCTORY

The Commission's proposed report for allocations from 25,000 kilocycles to 30,000,000 kilocycles was dated January 15, 1945. Provision was made at that time for oral argument on this report by any interested person. By subsequent public notice** it was provided that in addition to presenting oral argument interested persons would be permitted to present any additional evidence or material that might have been developed since the close of the hearing. These further hearings were held on February 28 to March 3, 1945, inclusive, and March 12, 1945. A list of the persons who appeared and presented statements and testimony at such oral argument is included in the appendix. Also included is a list and description of the exhibits that were introduced at these further hearings.

It appeared at the further hearing that much of the data and evidence concerning propagation was of a classified nature and hence could not be discussed in

---

* Dated May 25, 1945.

** Copies of all public notices issued subsequent to the proposed report are included in the appendix. (Not published with these excerpts—Ed.)

an open hearing. It was also apparent that it was not possible to reach a final determination unless this evidence were produced and made subject to cross-examination by interested persons. Accordingly, a closed hearing was arranged under the supervision of the military services for the presentation of such material. These hearings were held on March 12 and 13, 1945. In addition to members of the Commission's staff, engineers representing interested persons who were cleared for that purpose were permitted to attend the hearing and to cross-examine the witnesses. It is the Commission's hope that as soon as security regulations permit, much or all of this classified material will be declassified and made available to the public. But until that happens, the material cannot be divulged. In this report, however, the Commission has relied upon the material presented in the closed hearings where relevant although for security reasons detailed discussion of this material is not possible at this time.

IV—THEATER TELEVISION

One brief, that of Columbia Broadcasting System, Inc., objected to the allocations proposed to be made to theater television. Oral argument was presented by Mr. Joseph H. Ream on behalf of that organization (Tr. 4910) and by Mr. Paul J. Larsen on behalf of the Society of Motion Picture Engineers (Tr. 4979–4986).

The Commission's Report (pp. 188–189) stated that while no specific frequencies would be allocated to theater television, consideration would nevertheless be given to applications for experimental authorizations in this field on frequencies between 480 and 920 megacycles allocated to broadcasting on the basis that the use of these frequencies would be discontinued when needed for the broadcast service. In addition, the several bands of frequencies above 1900 megacycles allocated for general experimentation were made available for experimentation with intra- and inter-city relay of theater television programs.

The Columbia brief objected to the assignment of any frequencies to either subscription radio or theater television. The reasons for denying these services any frequencies were presented in detail as to subscription radio and were stated to "apply with at least equal force to the requested use of frequencies for theater television" (Brief, p. 36), although not separately treated. In brief, Columbia's position is that theater television is not broadcasting and hence should be assigned frequencies allocated to point-to-point services, if at all. In addition, Columbia made the point that theater television could use wire lines.

Mr. Larsen disputed the validity of these reasons, as applied to theater television, stating that theater television was admittedly not to be considered a broadcast service, and the Society's request for frequencies had been made on the express basis that the Commission would classify theater television as communications of a private nature so as to differentiate the service from broadcasting. With respect to utilization of wire lines for theater television he stated that wire lines are technically and economically impractical as well as inflexible and that present wire lines are not suitable for transmissions of channel widths greater than four megacycles. He pointed out that 85,000,000 people per week are entertained at theaters and, therefore, the proposed theater television service is obviously not of a limited character.

The Society of Motion Picture Engineers accordingly requested the Commission to reaffirm its experimental allocations for the theater television service in the several experimental bands above 1000 megacycles with the single modification that the final allocation make it clear that multiple address stations would be permissible at these frequencies as well as in the 480–920 megacycle band. It also requested the Commission to reaffirm its allocation of frequencies between 480 and 920 megacycles, but with the following two modifications: (*a*) Place television on a "parity of opportunity basis" with television broadcasting. (It was explained that this did not mean an equal sharing of these frequencies as theater television, employing directive networks, will require far less frequencies than broadcasting; but theater television felt that its service had, with television broadcasting, an equal responsibility to the public in the visual and aural entertainment field and allocations should accordingly be made to theater television as a competitive service to television broadcasting.) (*b*) Make the allocations to theater television between 480 and 920 megacycles permanent if the results of experimentation demonstrate that theater television can make better use of this band than of higher frequencies.

Both these requests the Commission has decided to grant, but not with the modifications suggested with respect to the use of the 480–920 megacycle band. Despite the probable future importance of the theater television service, it is felt that insufficient information is now available to make a specific determination of the needs of this service for spectrum space. Provision will therefore be made for experimentation in this new service in order to obtain information for a more precise determination of need at a later time when further consideration will be given to the availability of wire circuits for this type of service. It is expected, moreover, that the band 480–920 megacycles will be used primarily for television broadcasting to the public, with higher frequencies being more properly utilized by theater television and relay operation. Theater television experimental operation permitted in the 480–920 megacycle band will therefore be subject to the use of and need for this band for television broadcast service directly to the public.

The allocation of frequencies as proposed in the Commission's Report of January 15, 1945, is accordingly made final except that the bands of experimental frequencies above 1000 megacycles allocated to Non-Government, Fixed and Mobile service and available for theater television experimental use, including multiple address purposes if the need for such use can be established, will be, as revised by this Report, as follows: 1325–1375, 1750–2100, 2450–2700, 3900–4400, 5650–7050, 10,500–13,000, 16,000–18,000 and 26,000–30,000 megacycles.

THE APPLICATION OF THE POLAROGRAPH TO THE ANALYSIS OF PHOTOGRAPHIC FIXING BATHS*

VAUGHN C. SHANER** AND MARY R. SPARKS**

Summary.—*The use of a polarograph in the analysis of photographic fixing baths for aluminum alum, chrome alum, sulfite, and silver is described. A Fisher Elecdropode was used in this work. The polarographic method is shown to have an accuracy within 5 per cent for each of these 4 materials, which is satisfactory for photographic purposes. The reproducibility of the method is shown to be within 3 per cent. This method of analysis for aluminum alum, chrome alum, and silver is in use in this laboratory instead of the gravimetric method which is considered more cumbersome and time consuming. The polarographic method of analysis for sulfite has also been found more convenient in this laboratory than the previously used volumetric method.*

OBJECT OF WORK

During the 24 years of its existence, the polarographic method of analysis has developed rapidly and many articles have been published describing its use in the analysis of various materials, among which were those by Evans, Hanson and Glasoe[1, 2, 3] concerning the measuring of the copper, sulfide, elon, and iodide contents of developers. As a result of the successful application of the polarographic method of analysis to developers, this laboratory decided to purchase a polarograph to be used in chemical technical service to the motion picture industry. Upon obtaining this instrument, it was successfully employed in an analysis of a developer for copper contamination and in a survey of the water from various Hollywood motion picture laboratories.

While the polarograph has been used satisfactorily for many things, as far as the authors could ascertain, no work has been reported on the application of the polarographic method of analysis to fixing baths which this laboratory is requested frequently to analyze. The method of analysis for alum, sulfite, and silver used has been that reported by Atkinson and Shaner.[4] While this method is satisfactory

* Presented Oct. 17, 1944, at the Technical Conference in New York.

** Motion Picture Film Dept., Eastman Kodak Co., Hollywood.

from the standpoint of accuracy, it is rather cumbersome and time consuming. It was decided to investigate the application of the polarograph to fixing bath analysis, with the hope that a less time-consuming method could be evolved.

PROCEDURE

The instrument used, the Fisher Elecdropode, is a manually operated instrument for obtaining polarographic waves. A water bath was used to maintain a constant temperature of 25 C. The procedure followed was that described by Lingane,[5] in which the Ilkovic equation,

$$i_d = kn\, D^{1/2} C m^{2/3} t^{1/6} \qquad (1)$$

in which i_d is the diffusion current in microamperes, n is the number of electron equivalents per molar unit of electrode reaction, D is the diffusion coefficient (sq cm per sec) of the reducible or oxidizable substance, C is its concentration in millimoles per liter, m is the rate of mercury flow from the dropping electrode in mg per sec, and t is the drop time in seconds, is used. According to Lingane,[5] k, n, and D are independent of the characteristics of the dropping mercury electrode capillary and the quantity $kn\, D^{1/2}$, or I, is experimentally determinable as $i_d/(Cm^{2/3}t^{1/6})$ I is referred to as the "diffusion current constant." If I is substituted in the Ilkovic Eq (1) and then it is solved for C, the equation,

$$C = \frac{id}{m^{2/3}t^{1/6}I} \qquad (2)$$

is obtained. Since m is independent of the potential of the dropping electrode and the medium in which the drops form,[5] it need not be measured more frequently than once a week, unless there is reason to believe that the capillary has become contaminated. However, t varies with the medium and with potential[5] so it is necessary to measure t at the potential at which the diffusion current is measured every time a determination is made. Since the diffusion current varies with the temperature,[6] it is necessary to control the temperature within $\pm 1/2$ C.

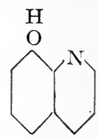
The current scale on a Fisher Elecdropode is not calibrated in amperes, so in order to use the equation given above, it was necessary to calibrate the galvanometer. The method used was that described by Kolthoff and Lingane[7] in which an 0–9999-ohm resistance box was hooked into the circuit in place of the electrolysis cell and calculations using Ohm's law were made. Diffusion current constants were calculated by measuring i_d for varying concentrations of the material in question when m and t were known and using Eq (2). The constants thus obtained are given in Table 1. Before each determination, nitrogen was bubbled through the solution for 5–10 min to free it of dissolved gases.

TABLE 1

Diffusion Current Constants

						Average
8-Hydroxyquinoline	2.84	3.56	3.61	2.98	3.54	3.30
Chromium	1.56	1.55	1.62	1.61	1.58	1.58
Sulfite	1.35	1.36	1.35	1.33	1.35	1.35
Silver	1.54	1.61	1.59	1.59	1.56	1.58

Aluminum.—A polarographic exploration of a fixing bath revealed a large wave which completely obscured the aluminum wave, so it was necessary to precipitate the aluminum from the fixing bath. A 50-ml sample of the fixing bath was taken and made just alkaline with ammonium hydroxide, heated to boiling, and filtered. The white precipitate of aluminum hydroxide was washed on the filter paper with hot ammonium nitrate and washed into a beaker with distilled water. The mixture was made acid with acetic acid and heated until the aluminum hydroxide dissolved. The volume was made up to 250 ml. It was discovered that the aluminum wave was covered by the hydrogen ion wave from the acid. For this reason, the following indirect method of determining aluminum was devised.

The hydrogen of the *OH* group of 8-hydroxyquinoline, 

is replaceable by aluminum in dilute acetic acid solution which is buffered with ammonium acetate.[8] 8-Hydroxyquinoline is polarographically determinable in a base electrolyte of ammonium acetate. Therefore, if the aluminum hydroxide precipitate from a fixing bath is dissolved in dilute acetic acid and allowed to react with an excess amount of 8-hydroxyquinoline reagent of known composition and a sample of the supernatant 8-hydroxyquinoline analyzed polarographically, the aluminum concentration can be calculated from the change in the 8-hydroxyquinoline concentration.

Take a 50-ml sample of fixing bath, make alkaline with ammonium hydroxide, filter, and wash with hot ammonium nitrate solution. Dissolve the precipitate in very dilute acetic acid solution and dilute to 250 ml with distilled water. Heat 10 ml of this solution to about 70 C and add 10 ml of 8-hydroxyquinoline reagent (25 gm 8-hydroxyquinoline in 60 ml glacial acetic acid, diluted to 2 liters with cold water) and 25 ml of 2 *N* ammonium acetate solution. Dilute to 100 ml and let stand until the precipitate settles. Add one ml of the supernatant liquid to 5 ml of 2 *N* ammonium acetate and 3 drops of 6 per cent gelatin. Dilute to 20 ml and determine polarographically the 8-hydroxyquinoline concentration.

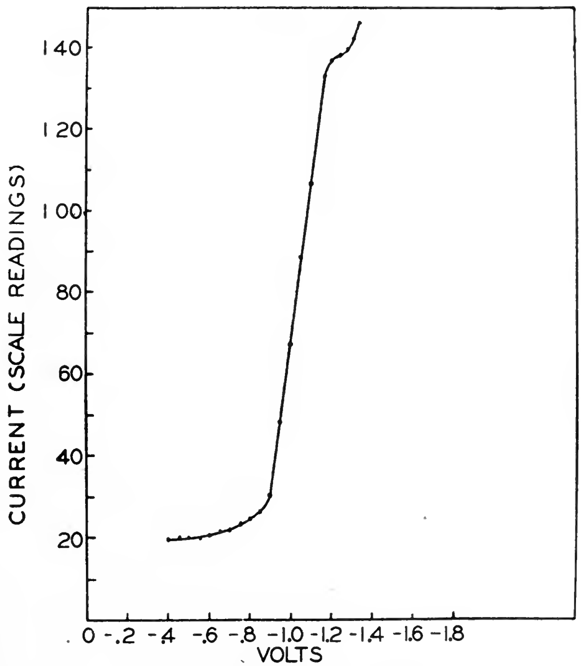


FIG. 1. 8-Hydroxyquinoline.

The difference in the value obtained and the 8-hydroxyquinoline concentration in the reagent diluted as described is the amount which reacted with the aluminum. A typical 8-hydroxyquinoline curve is shown in Fig. 1. The wave starts at a potential of about −0.8 v and levels at a potential of about −1.2 v. Typical diffusion current constants are shown in Table 1.

Sample Calculation.—If i_d = 2.197 μa, m = 2.2019 mg per sec, t = 2.68 sec, and

$I = 3.30$, the concentration of 8-hydroxyquinoline in the electrolysis cell may be calculated by substitution in Eq (2) as follows:

$$C = \frac{2.197}{(2.2019)^{2/3}\,(2.68)^{1/6}\,3.30}$$

= 0.337 millimole of 8-hydroxyquinoline per liter.

Since one ml of unknown is diluted to 20 ml in the electrolysis cell,

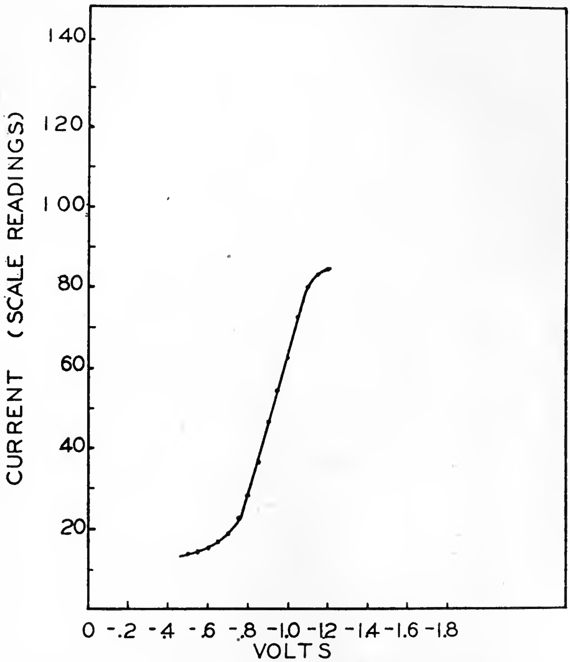


FIG. 2. Chromium.

$\frac{0.3337 \times 20}{1000}$ = 0.006674 molar 8-hydroxyquinoline in solution with aluminum precipitate. 8-Hydroxyquinoline reagent is 0.0858 *M*, but is diluted 10 times before it is allowed to react with aluminum.

$$0.00858 - 0.00667 = 0.00191\ N \text{ aluminum}$$

In order to convert this value to gm per liter of aluminum alum

$\frac{0.00191 \times 100 \times 250 \times 474.38}{3 \times 50 \times 10}$ = 15.10 gm potassium aluminum per liter of fixing bath.

Chromium.—As in the case of the aluminum wave, the chromium wave was found to be obscured by the fixing bath wave. Chromium was precipitated and washed with ammonium nitrate like the aluminum. The blue-green precipitate of chromium hydroxide was dissolved in dilute hydrochloric acid and the volume of solution made up to 500 ml. One ml of this solution was taken for polarographic analysis, added to a base electrolyte of 5 ml of 0.4 *N* calcium chloride, and diluted to 20 ml with distilled water. No gelatin was added. The chromium wave starts at a potential of about −0.6 v and levels off at a potential of about −1.2 v.[9] A typical wave is shown in Fig. 2 and typical diffusion current constants for chromium are shown in Table 1.

Sample Calculation.—If i_d = 1.0 μa, m = 2.2019 mg per sec, t = 3.18 sec, and I = 1.58, then the concentration of chromium in the electrolysis cell may be calculated by substitution in Eq (2) as follows:

$$C = \frac{1.0}{(2.2019)^{2/3}\,(3.18)^{1/6}\,1.58}$$

$$= 0.3084 \text{ millimole } Cr^{+++} \text{ per liter.}$$

Then to convert this value to gm per liter of chrome alum

$$\frac{0.3084 \times 20 \times 500 \times 499.42}{1000 \times 50} = 30.80 \text{ gm chrome alum per liter of fixing}$$

bath.

Sulfite.—In neutral or alkaline solution, sulfite ion is not reducible at the dropping mercury electrode, but in acid solutions a well-defined wave is obtained.[10] The diffusion current will vary with the *p*H of the solution, so it is necessary to use a buffer as the base electrolyte. A *p*H 4.0 buffer composed of 27.48 gm per liter of $Na_2HPO_4 \cdot 12\,H_2O$ and 5.90 gm per liter of citric acid proved satisfactory. It was noticed that if the diffusion current of the sulfite ion was greater than 15 μa, the current was not directly proportional to the concentration of the sulfite ion present. Therefore, the size of the sample of fixing bath must be chosen accordingly. If the fixing bath contains less than 10 gm per liter, one ml sample may be used; if it contains more than 10 gm per liter, or gives a diffusion current greater than 15 μa, a 1/2-ml sample may be used.

A 1/2-ml sample of fixing bath may be obtained by diluting 25 ml of the fixing bath to 50 ml with distilled water and taking one ml of the diluted mixture. The fixing bath sample is added to 10 ml of the *p*H

4.0 buffer and 3 drops of 6 per cent gelatin, and the whole is diluted to 20 ml for polarographic measurement. A typical wave is shown in Fig. 3. The wave starts at a potential of about −0.2 v and levels off at a potential of about −0.6 v. Typical diffusion current constants are shown in Table 1.

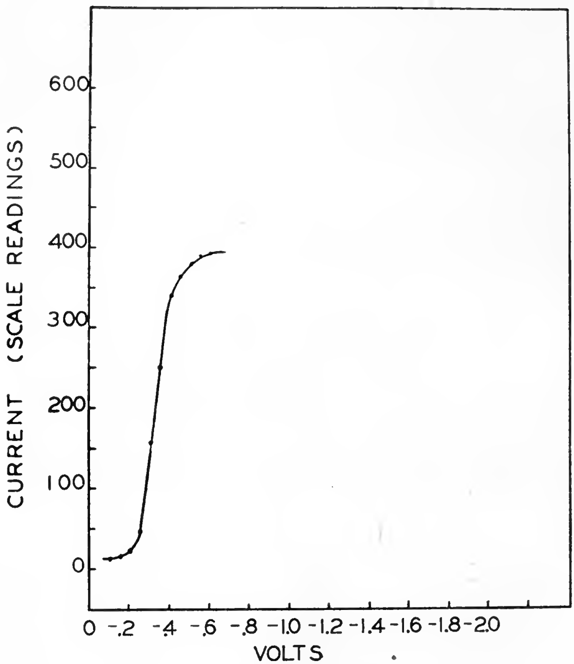


FIG. 3. Sulfite.

Sample Calculation.—If $i_d = 5.9$ μa, $m = 2.2019$ mg per sec, $t = 3.04$ sec, and $I = 1.35$, the concentration of sulfite in the electrolysis cell can be expressed by substitution in Eq (2) as follows:

$$C = \frac{5.9}{(2.2019)^{2/3}\,(3.04)^{1/6}\,1.35}$$

$$= 2.146 \text{ millimoles } SO_3^{=} \text{ per liter of solution.}$$

In order to convert this value to gm per liter of Na_2SO_3

$$\frac{2.146 \times 20 \times 126.05}{1000} = 5.41 \text{ gm sodium sulfite per liter of a fixing bath.}$$

Silver.—A well-defined diffusion current is obtained from the reduction of silver thiosulfate ion from a solution of sodium thiosulfate.[11] This wave starts from 0 applied potential. To assure a large concentration of thiosulfate ions, 10 ml of 0.1 *N* sodium thiosulfate were used as the base electrolyte. One ml of the unknown fixing bath and 3 drops of 6 per cent gelatin to prevent maxima were added. This solution was diluted to 20 ml and placed in the elec-

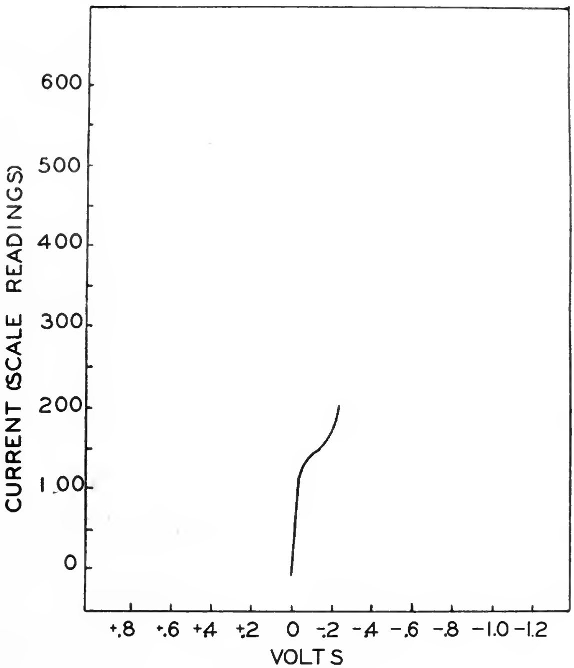


FIG. 4. Silver.

trolysis cell for polarographic determination. A typical wave is shown in Fig. 4. It is advisable to make a determination on a blank solution, so that any current carried by the base solution alone may be subtracted from the current carried by the silver and the base solution. To determine the diffusion current constant *I*, known quantities of silver nitrate were added to a fixing bath and the diffusion currents were measured as described above. The diffusion current constants thus found are reported in Table 1. The average value was used in analysis.

Sample Calculation.—If the measured value of $i_d = 4.9\ \mu a$, $m = 2.2019$ mg per sec, $t = 3.22$ sec, and $I = 1.58$, then the concentration of silver in the electrolysis cell may be determined by substitution in Eq (2) as follows:

$$C = \frac{4.9}{(2.2019)^{2/3}\,(3.22)^{1/6}\,1.58}$$

$$= 1.508 \text{ millimoles } Ag^{+} \text{ per liter or}$$

$$\frac{1.508 \times 20 \times 107.88}{1000} = 3.25 \text{ gm silver per liter.}$$

Hypo.—An attempt was made to analyze a fixing bath for sodium thiosulfate by polarographic means. The thiosulfate ion gives a polarographic anodic wave at a potential of about −0.25 v. This value is shifted to a more positive potential if the thiosulfate ion concentration is very great.[12] In order to put the thiosulfate ion concentration of a fixing bath within the range determinable on a polarograph, the fixing bath would have to be diluted. This dilution frequently resulted in decomposition of some of the thiosulfate into sulfur and sulfite. For this reason, it is recommended that the iodine titration method of Atkinson and Shaner[4] be used to determine the total amount of hypo and sulfite present. The sulfite can be determined polarographically, subtracted from the total, thus giving the quantity of hypo present without employing a formaldehyde titration.

RESULTS

Accuracy.—To determine the accuracy of the method, 4 analyses of fixing baths of known composition were made. The results of these analyses are given in Table 2. From these data it can be seen that the method is accurate within 5 per cent for aluminum, chromium, and silver. The high per cent error of sodium sulfite in the chrome alum fixing bath is believed to be caused by the escape of part of the sulfite added to the fixing bath as sulfur dioxide, because of the high degree of acidity of a chrome alum fixing bath. The sulfite concentration of the fixing bath was checked iodometrically and found to agree with the polarographic results. It is to be noted that this high error did not occur in the analysis of potassium aluminum alum fixing baths. For these reasons and because of the reproducibility of a sulfite constant, it is concluded that the accuracy of the polarographic sulfite analysis is within 5 per cent. Since it is a generally accepted fact that a change in concentration of 10 per cent of a chemical in a fixing bath is necessary to show any photographic effect, the accuracy of this analytical method is quite satisfactory.

Reproducibility.—The reproducibility of the method was tested by analyzing a potassium aluminum alum fixing bath and a potassium chromium alum fixing bath 6 times apiece. The data thus collected are given in Tables 3 and 4. From Table 3, it can be seen that in 6 analyses of a potassium aluminum alum fixing bath, the greatest deviation from the mean in a sulfite analysis is 1.86 per cent, in an aluminum analysis the greatest deviation from the mean is 2.19 per cent, and in a silver analysis the greatest deviation is 2.6 per cent. From Table 4 it can be seen that in 6 analyses of a chrome alum fixing bath the greatest deviation from the mean in the sulfite analysis is 1.40 per cent, the greatest deviation from the mean in the chromium analysis is 2.22 per cent, and the greatest deviation from the mean in the silver analysis is 2.83 per cent. Thus, it may be concluded that the reproducibility of analyses made by this method is quite satisfactory.

Time of Analysis.—The polarographic method of analysis is much less time consuming than the regular method

TABLE 2

Accuracy

	Fixing Bath *A*			Fixing Bath *B*			Fixing Bath *C*			Fixing Bath *D*		
	Gm/L Added	Gm/L Found	Per Cent Error	Gm/L Added	Gm/L Found	Per Cent Error	Gm/L Added	Gm/L Found	Per Cent Error	Gm/L Added	Gm/L Found	Per Cent Error
Potassium Aluminum Alum	...	...	...	...	...	...	10	9.60	4.0	5	4.82	3.6
Potassium Chromium Alum	40	39.48	1.3	32	30.81	3.72	...	...	...	...	...	...
Sodium Sulfite	20	12.93	3.5[1]	16	12.85	4.42[2]	10	10.25	2.5	5	5.2	4.0
Silver	0	0	0	0.18	0.18	0	6.2	5.94	4.2	3.1	3.16	1.9

[1] Based on iodometric measurement of 13.4 gm per liter = 100 per cent.
[2] Based on iodometric measurement of 12.3 gm per liter = 100 per cent.

of analysis. A polarographic silver analysis requires only about 15 min as compared with the considerably longer time required for a gravimetric silver analysis. Polarographic chromium and aluminum analyses require the same length of time for precipitation as the gravimetric chromium and aluminum analyses, but do not require

TABLE 3

Reproducibility

Six Analyses of Potassium Aluminum Alum Fixing Bath M

Sodium Sulfite		Potassium Aluminum Alum		Silver	
Gm/L	Per Cent deviation from Mean	Gm/L	Per Cent deviation from Mean	Gm/L	Per Cent deviation from Mean
15.75	+1.02	15.18	−2.94	0.39	+2.6
15.30	−1.86	15.10	−3.45	0.39	+2.6
15.87	+1.79	15.98	+2.19	0.38	0
15.52	−0.45	15.90	+1.66	0.38	0
15.55	−0.26	15.85	+1.34	0.38	0
15.57	−0.13	15.84	+1.28	0.38	0
Average:					
15.59		15.64		0.38	

TABLE 4

Reproducibility

Six Analyses of Chrome Alum Fixing Bath N

Sodium Sulfite		Chrome Alum		Silver	
Gm/L	Per Cent deviation from Mean	Gm/L	Per Cent deviation from Mean	Gm/L	Per Cent deviation from Mean
12.80	0	31.48	+1.41	1.34	−2.16
12.64	−1.24	30.65	−1.25	1.41	+2.83
12.98	+1.40	31.73	+2.22	1.37	0
12.76	−0.31	30.39	−2.09	1.33	−2.83
12.84	+0.31	30.81	−0.74	1.39	+1.46
12.79	−0.39	31.17	+0.42	1.38	+0.73
Average:					
12.80		31.04		1.37	

the long time for ignition and weighing of the precipitates. Polarographic sulfite analysis requires as much time as the iodometric method, but the use of formaldehyde and ice, which is required in the iodometric method,[4] is not necessary.

It should be emphasized that the use of a polarograph, like any scientific precision instrument, requires considerable experience by a qualified chemist before reliable results can be obtained. The authors have found the text "Polarography" by Kolthoff and Lingane to be almost indispensable as a guide and reference in developing a technique for the operation of this instrument.

The authors wish to express their grateful appreciation to Emery Huse under whose guidance this work was undertaken and completed. In addition, they wish to acknowledge the helpful suggestions of various members of the Kodak Research Laboratories.

CONCLUSION

(*1*) Polarographic methods of analysis may be satisfactorily applied to the aluminum alum, chrome alum, sulfite, and silver contents of photographic fixing baths.

(*2*) The accuracy of the polarographic analytical method is within 5 per cent for these 4 photographic fixing bath constituents.

(*3*) The results of the polarographic analyses for the above-named fixing bath constituents are reproducible within 3 per cent.

(*4*) It was the experience of the authors that the polarographic method of analysis for sodium thiosulfate in fixing baths is less practical than the conventional iodometric method of analysis.

(*5*) Analysis of fixing baths for aluminum alum, chrome alum, and silver by polarographic means is less cumbersome and time consuming than analysis by gravimetric methods. The polarographic method of analysis for sulfite has also been found more convenient in this laboratory than the previously used volumetric method.

REFERENCES

[1] EVANS, R. M., HANSON, W. T., AND GLASOE, P. K.: "Iodide Analysis in M. Q. Developers," *J. Soc. Mot. Pict. Eng.*, **XXXVIII,** 2 (Feb., 1942), p. 180.

[2] EVANS, R. M., HANSON, W. T., AND GLASOE, P. K.: "Synthetic Aged Developers by Analysis," *J. Soc. Mot. Pict. Eng.*, **XXXVIII,** 2 (Feb., 1942), p. 188.

[3] EVANS, R. M., HANSON, W. T., AND GLASOE, P. K.: "Copper and Sulfide in Developers," *J. Soc. Mot. Pict. Eng.*, **XL,** 2 (Feb., 1943), p. 88.

[4] ATKINSON, R. B., AND SHANER, V. C.: "Chemical Analysis of Photographic Developers and Fixing Baths," *J. Soc. Mot. Pict. Eng.*, **XXXIV,** 5 (May, 1940), p. 485.

[5] LINGANE, J. J.: "Systematic Polarographic Metal Analysis," *Ind. Eng. Chem., Anal. Ed.*, **15** (1943), p. 588.

[6] KOLTHOFF, I. M., AND LINGANE, J. J.: "Polarography," Interscience Publishers, Inc. (New York), 1941, p. 249.

[7] KOLTHOFF, I. M., AND LINGANE, J. J.: *Ibid.*, p. 228.

[8] TREADWELL, F. P., AND HALL, W. T.: "Analytical Chemistry," John Wiley and Sons, Inc. (New York), 1935, p. 98.

[9] KOLTHOFF, I. M., AND LINGANE, J. J.: *Ibid.*, p. 291.

[10] KOLTHOFF, I. M., AND LINGANE, J. J.: *Ibid.*, p. 312.

[11] KOLTHOFF, I. M., AND LINGANE, J. J.: *Ibid.*, p. 259.

[12] KOLTHOFF, I. M., AND LINGANE, J. J.: *Ibid.*, p. 326.

PROGRESS REPORT OF THE WORK OF THE ASA WAR COMMITTEE ON PHOTOGRAPHY AND CINEMATOGRAPHY, Z52*

J. W. McNAIR**

This is the third report on the work of the American Standards Association War Committee on Photography and Cinematography, Z52, which has been presented before a semi-annual technical conference of the Society.

Since the last conference some 16 new American War Standards have been completed, approved, and made available for the use of the Armed Forces and industry. This brings to 41 the total number of American War Standards for photography and motion pictures thus far completed. Active work on 30 additional projects is well under way while work authorized on 7 other subjects will be begun as soon as the time and personnel are available.

The standards which have been completed since the October, 1944, Conference of the Society include several which will be of considerable future importance to the science of motion picture engineering. I have been told by a number of members of the Society that, in their opinion, some of these can be adopted with little, if any, change as regular American Standards under the Society's sponsorship of the ASA Sectional Committee on Motion Pictures, Z22.

Most important of these new standards to be completed since last October is the American War Standard Nomenclature for Motion Picture Film Used in Studios and Processing Laboratories, Z52.14-1944. Some 5000 copies of this standard have been required by the Armed Forces alone for distribution to the service personnel concerned, while an additional 3000 copies have been made available to the industry in pamphlet form.

Moreover, the Society has deemed this War Standard of such im-

---

* Presented May 14, 1945, at the Technical Conference in Hollywood.

** Secretary, War Committee on Photography and Cinematography, American Standards Association, New York.

portance in clarifying the confusion in nomenclature which exists that it has reprinted the document *in toto* in the April, 1945, issue of the Journal.

With regard to the quality control of 16-mm film, 3 additional standards have been completed: the American War Standard Method of Making Intermodulation Tests on Variable-Density 16-Mm Sound Motion Picture Prints, Z52.15-1944, American War Standard Method of Making Cross-Modulation Tests on Variable-Area 16-Mm Sound Motion Picture Prints, Z52.39-1944, and American War Standard Specification for Warble Test Film Used for Testing 16-Mm Sound Motion Picture Equipment, Z52.32. One additional standard on 16-mm print quality control remains to be completed, American War Standard Method of Determining Printing Loss in 16-Mm Sound Motion Picture Prints, Z52.40. A preliminary draft of this standard, prepared by Dr. Otto Sandvik and J. A. Maurer, is now receiving its final polishing before circulation to the members of the Subcommittee *B* on 16-Mm Sound. It is expected that this proposed standard will be one of the most comprehensive documents which has dealt with this subject, on which little has appeared in the technical literature in the past.

Another standard in the 16-mm field which is of extreme importance to all concerned, is the new American War Standard Specification for 16-Mm Motion Picture Projection Reels and Containers, Z52.33-1945. This new standard lists for the first time a comprehensive set of dimensions and performance requirements for reels which will assure a reasonable long service life and provide for proper operation on existing projectors. In this connection, I wish to compliment D. F. Lyman, Chairman of the Nontheatrical Committee of the Society, who served as the Chairman of the Subgroup on Reels, for the excellent analysis he made of the dimensional requirements for reels and reel spindles necessary for the proper projection of 16-mm sound film. Mr. Lyman's detailed study formed the firm engineering basis for the work of the War Committee. Incidently, a new American War Standard for Reel Spindles for 16-Mm Motion Picture Projectors, Z52.34-1945, has also resulted from the work of the Subgroup.

In the 35-mm field, one new standard has been approved since my last report. That is the all-important War Standard for Sound Records and Scanning Area of 35-Mm Sound Motion Picture Prints, Z52.36-1945. This standard was recommended to the War Committee following much work by both the technical committees of the

Society and of a committee of the Research Council of the Academy of Motion Picture Arts and Sciences. As you know, in the past there was no complete agreement between all branches of industry on the proper dimensional standards for 35-mm sound film. It is hoped that this War Standard, when considered in connection with certain wartime developments in the art of making raw stock, may result in a firm agreement on standards for post-war use.

The subject of proper tests for judging noise generated by motion picture cameras has been one on which there was not too much information previous to the war. Subcommittee *J*, jointly organized by the Research Council and the Society, has now drawn up a specification which has been approved as American War Standard Camera Noise Test, Z52.60, which should do much to alleviate problems which have arisen in the past from the use of noisy cameras. The development of this standard was carried out here in Hollywood under the direction of Gordon E. Sawyer.

Another group of war standards which have been approved in the motion picture field are Screens—Sizes, Z52.41; Screens—Sound Transmission, Z52.44; Screens—Brightness, Z52.46; and Screens—Whiteness, Z52.45. These standards contain the essential screen requirements for proper projection of motion pictures under both Armed Forces and professional conditions. These standards also form the basis for another group of 4 specifications for spring-roller, springless-roller, folding, and frame-mounted screens which are intended for eventual adoption as joint Army-Navy procurement specifications for the Armed Forces.

Proposed standards for both 16-mm and 35-mm camera viewfinder apertures, lens mounting dimensions, and lens registration distances are still under development and it is hoped that this work will be completed in the next 60 days.

With the growing amount of direct 16-mm equipment, efforts are also being made to crystallize war standards which will stabilize the interchangeability situation as far as 16-mm camera film magazines are concerned. Draft standards have now been drawn up for the 400-ft gear-driven magazine and for both 200-ft and 400-ft belt-driven magazines.

A proposed standard nomenclature for optical filters, which is based on the spectrophotometric characteristics of the filters, is now nearing its final draft stage. As you know, this subject has been one which has caused much difficulty in the past since many users of filters are not quite clear as to the way in which filters affect the picture recorded on the film. In some cases, users have judged filters by their spectral appearance rather than by their radiometric characteristics with the unfortunate results which might be expected. There has been no information available to the industry as to the filters of different manufacturers which are equivalent photographically from the standpoint of their spectrophotometric curves. With the adoption of a standard nomenclature, such difficulties will disappear.

Another project now underway which is of great interest to the members of the Society, is for standard synchronization marks for both 35- and 16-mm release print negatives and other preprint material. As some of you may know, there have been no accepted standards on this subject since the birth of sound on film. Each laboratory and producer has used his own peculiar system of identifying editorial and projection synchronism for both 35 and 16 mm. With the wartime interchange of negatives between producers and the Armed Forces, by the Armed Forces themselves, among producers, and among processing laboratories, the differing systems of synchronization marks have caused much confusion and loss of time in printing and inspection as well as wastage of much film. As the result of the circulation of draft standards to the Armed Forces and the interested committees of the Research Council and the Society, a number of changes have been suggested in the tentative proposal circulated in March, 1945. This has now been modified and the new draft is now before both the Society and the Council for their recommendations on its proposed submission to letter ballot of the War Committee.

There are several other standards pertaining to motion pictures such as those for camera motors, 16-mm warble test films, *etc.*, which are still under development.

I should also like to say a few words as far as the subject of war standards for still pictures is concerned, since many members of the Society are also interested in these standards. Most important of the standards for still pictures to be completed since the last conference of this Society is the American War Standard Specification for Photographic Flash Lamps, Z52.43. This purchase specification which has since been adopted as Federal Specification, *W-L-122*, for use by all procuring agencies of the U. S. Government, is the first ever to be written on the subject of flash lamps. The method of approach used in writing this specification was to rate the lamps on the basis of their picture-taking qualities, rather than on the total amount of light output, or the peak light output, which so many lamp users have attempted to use as a guide in rating lamps in the past.

Other still photographic standards adopted included one for 35-mm slide films which are also used extensively for training and instructional purposes and another for testing the resolution of slide-film projector lenses. Proposed standards for still contact printers and for slide-film projectors are in the final stages of approval. In addition much work has been done on standard test methods for both between-the-lens and focal-plane shutters and on the standardization of shutter markings.

As you may judge from the above brief report, the amount of detail involved in conducting the work of the War Committee has been quite extensive. All in all, 191 drafts alone have been circulated to the War Committee and its subcommittees on the 71 projects which have either been approved or reached a satisfactory stage to merit assignment of an identification number.

The part the Society and its officers played in the work of the War Committee has been a large one and without their cooperation much of this work could never have been accomplished. The Research Council of the Academy has been extremely helpful, particularly with regard to the standards for 35-mm motion pictures, since it has helped us to a very great extent by assuming the secretarial burden for three of the subcommittees which have been active.

In conclusion, I should like to say that copies of the various American War Standards, which have been approved, may be obtained from the American Standards Association's offices in New York by those who have not already done so. Copies of the various draft standards, which are under consideration, will be gladly furnished, without charge, to anyone who is interested.

AN AUTOMATIC HIGH-PRESSURE MERCURY ARC LAMP CONTROL CIRCUIT*

LESTER F. BIRD**

Summary.—*A description is presented of a new high-pressure mercury arc lamp with associated control circuits in which optical inverse feedback is employed to produce an adjustable lamp capable of high stability and uniformity of output suitable for use in printers. Curves illustrating performance are included and discussed with possibilities for use of this lamp in variable-density recording.*

HISTORY OF MODULATED AND CONTROLLED MERCURY ARC LAMPS

Prior to the development of the hot cathode type of high-pressure mercury arc lamps no methods of intensity control or modulation were successful because of two inherent characteristics in the mercury pool type. The first of these was nonlinear relations between light output and power input, and the second, instability caused by the movements of the cathode spot on the mercury pool. The cathode spot in such arcs is in constant motion because the evaporation of mercury under the spot moves it rapidly from place to place and results in flutters in the current through the lamp as well as changes in the position of the arc stream within the envelope. The light from the arc is continually varying.

With the development of the solid activated electrodes for the high-pressure mercury arc lamps the unstable cathode spot was eliminated, but the arc still retained the nonlinearity between the input and the light output. The light output was not proportional to either the current or the power input.

Fig. 1 illustrates some curves plotted from data taken on a 100-w high-pressure capillary type of mercury vapor arc lamp both for the starting condition before the lamp was warmed appreciably and for the hot condition when it was operating normally. The nonlinearity between the light output and the arc current is very apparent and indicates that there can be considerable current flow when the light

---

* Presented Oct. 16, 1944, at the Technical Conference in New York.

** Hanovia Chemical and Manufacturing Co., Newark, N. J.

has practically disappeared. Should an attempt be made to modulate such a lamp it is obvious there would be noticeable distortion and the result would be disappointing.

Another and unexpected defect in the light output from the mercury arc when applied to recording was the presence of a very high-frequency audible hiss which interfered seriously with high-fidelity results. The hiss is believed to originate in the mercury molecule itself during the process of ionization.

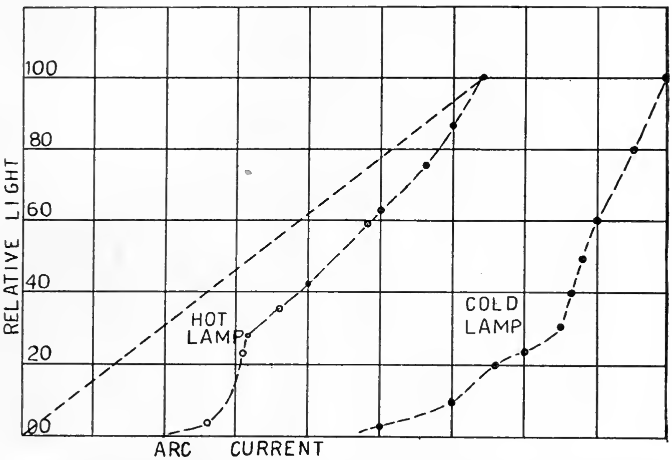


FIG. 1. Performance curves of a high-pressure mercury vapor arc lamp illustrating variations of relative light output for current input taken on a cold lamp immediately after starting, and on a normally operating one.

About the year 1926 James R. Balsley conceived the idea of applying inverse feedback circuits to the control of the light output characteristics of mercury arcs. His work resulted in U. S. Patent No. 2,242,638 from which a summary is taken as follows.

The object was to produce a control circuit which would operate in conjunction with a high-pressure mercury arc to produce a lamp whose light output remained at a steady level during variations in operating conditions that normally resulted in changes in light output. Such conditions were changes in ambient temperature, drafts of air against the arc tube, deterioration of the arc tube, variations in the electric power supply, variations inside the arc tube caused by varying mercury vapor pressures, *etc.*

Mr. Balsley operated a d-c mercury vapor arc lamp having solid activated electrodes from a d-c source using triode radio tubes for the main stabilizing resistance. All or most of the current for the arc lamp passed through these triode tubes and was controlled by them. He then placed a photocell at a place where light from the arc lamp could fall upon it and by means of an amplifier, the output of the photocell was fed back into the control grids of the main triodes. The photocell was so connected that an increase in the light reaching it caused a response which reduced the input to the arc lamp, while a reduction in the light reaching the photocell caused an increase in the current reaching the arc lamp. The action of the phototube

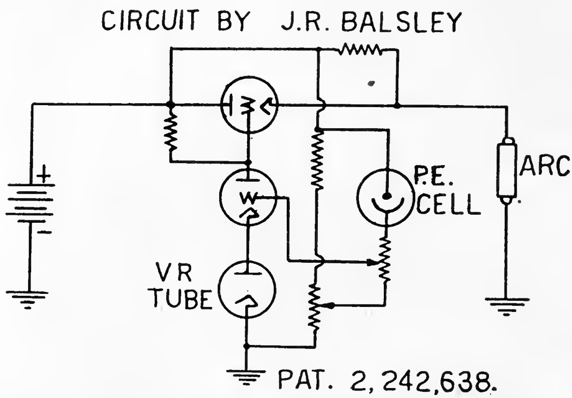


FIG. 2. Control circuit published by J. R. Balsley in U. S. Patent No. 2,242,638.

therefore was always to reduce or entirely prevent changes in the strength of the light reaching it. It could thus hold the light steady at whatever level the circuit adjustments permitted.

The circuit published by Mr. Balsley is shown as Fig. 2, and a rearrangement of it is shown in Fig. 3 to make its operation more understandable. There is one feature of this circuit of special note because of the variation in potential to ground of the cathode of the main control triode. Since the voltage passes through this tube to the arc lamp the cathode potential varies with the arc voltage. The grid of the main triode is connected in a circuit which does not vary with the arc lamp voltage and as a result we experienced some difficulty in maintaining stable circuit conditions when experimenting with this circuit.

It was essential that the performance of the control circuit be known to determine how well it served to perform the main purpose of maintaining a steady output of light. We investigated it in the following manner.

The light output of the arc lamp was measured while we varied the length of the optical path between the arc lamp and the control photocell. Since the circuit responded in such a manner as to try to maintain constant light reaching the control photocell when this cell was moved toward or away from the arc lamp, the light output of the lamp became the variable with distance instead of a varying photocell response which is the usual effect. It therefore results that the light output of the arc lamp must vary with changing distances between it

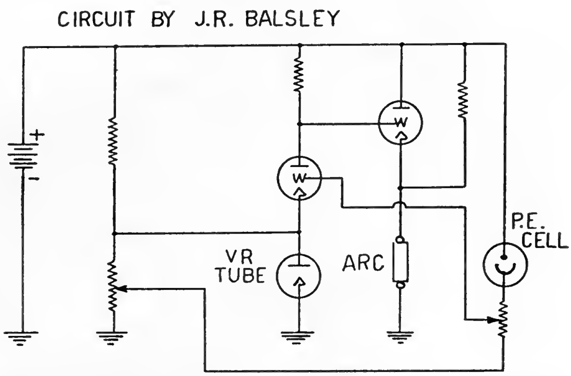


FIG. 3. Redrawn circuit of Fig. 2 to simplify the arrangement of the parts.

and the photocell in accordance with the well-known laws of optics covering the strength of light at varying distances from a source. If the light at the control photocell were to be held constant as the cell was moved, the light source would, assuming the inverse square law to be operative, have to give out 4 times as much light when the cell was moved twice as far away.

Since the distance from the lamp to the cell was easily measurable, a setup was made (Fig. 4) in which the lamp was mounted at a fixed location with an auxiliary independent photocell beside it to measure its light output. Then the control cell was mounted on a moveable car. Measurements were made of the response of the control cell to show the variations in light reaching it and also the variations of light at the lamp. For a theoretically perfect system, the light at the lamp should vary as the square of the distance to the photocell, and the light at the control cell remains constant. Fig. 5 illustrates the results of these measurements. They show that the light at the lamp did not increase enough with the distance changes to the photocell and that the light at the control cell fell off markedly with a change in distance instead of remaining constant. In other words, the control ability of the photocell was unable to maintain the light output constant since rather large changes in the light reaching it were necessary to initiate the control action. The curves given are in no sense presented as a critical or exhaustive study since they are only plotted

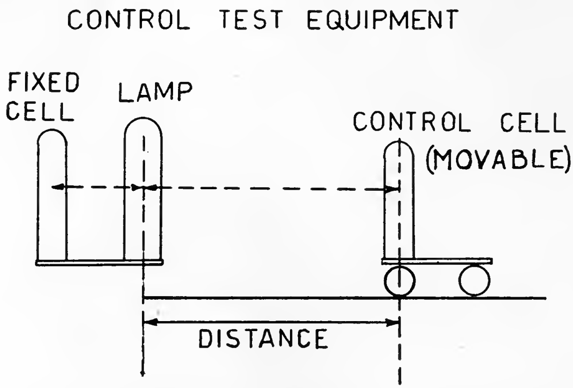


Fig. 4. Arrangement of equipment used to determine the characteristics of the control circuits. Light variations at the lamp were measured with the fixed cell. Light variations were determined at the control cell as it was moved to various distances from the lamp.

data taken on our setup of Mr. Balsley's circuits. On another arrangement with different components the results might have been different.

This amount of control was held to be insufficient and new circuits were developed to increase the sensitivity of the feedback control. Fig. 6 illustrates the new circuits. Two sources of voltage are used for stability reasons and both are obtained from rectifiers. The arc lamp is connected next to the positive voltage end of the supply with the control tubes next to ground in such a manner that the cathodes of these tubes were at ground potential. This arrangement permitted close regulation of the grid potentials at all times. The power tube grids were operated by a pair of *6L6* beam power tubes. The control grids of the *6L6's* were operated by a single *6SF5* high mu triode.

Performance curves for this circuit were taken with the same experimental procedure used for the other circuits and the results are shown in Fig. 7. The light output of the lamp is shown to be very near the theoretically correct values for all positions of the control cell and the light reaching the control cell varied but slightly with distance. Such performance indicated ability of the cell to exercise high stabilizing effects throughout a wide range of light output levels.

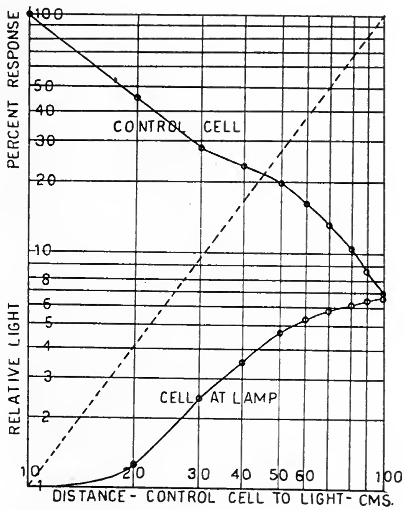


FIG. 5. Performance curves of circuits set up by Hanovia based on those published by J. R. Balsley in U. S. Patent No. 2,242,638.

Tests of performance were also made by the use of an oscilloscope. Light from the lamp was received upon a photocell and connected to the oscilloscope to test visually the effectiveness of the control. Ripples and variations that were visible in the light when the feedback cell was inoperative were seen to be greatly reduced as soon as the feedback was re-established. Disturbances in the light that were introduced from external sources were compensated for to a maximum extent. A test film was obtained having a wide variety of densities and was passed between the light and the control cell. The circuit response was such that the light passing through the various densities of film was maintained almost constant, suggesting a possible use of such a control system for automatic control of printing processes.

Tests were made to show the stability of the light levels when they were changed from one output to another over a period of time to test the ability of the circuit to maintain the light constant. These tests indicated that the light could be adjusted within a complete range of about 11 to one, be changed instantaneously from one level to any other level, and remain steady at the new level.

IMPROVEMENTS IN THE MERCURY ARC LAMP

During the development of a satisfactory control circuit it was found necessary to develop a new type of mercury arc lamp that would be able to operate with the control circuit. The simple form of high-pressure mercury arc lamp was not satisfactory for the purpose. The usual mercury arc lamp is designed to contain a limited

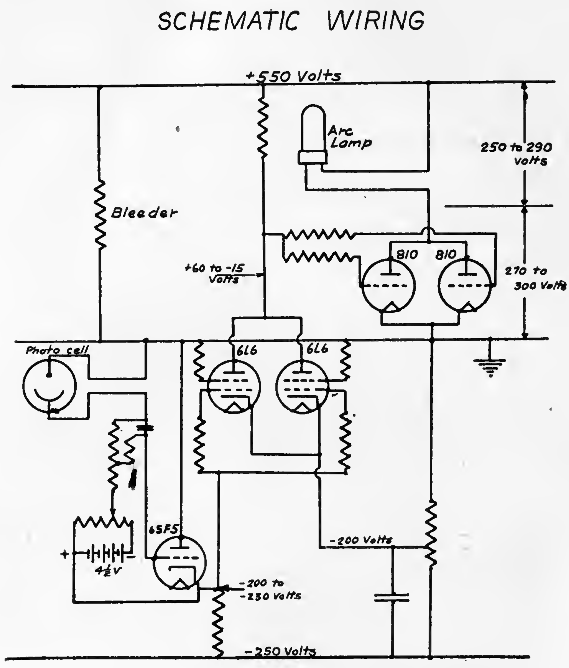


FIG. 6. New circuits developed for the control of a mercury arc lamp by the use of optical inverse feedback.

quantity of mercury which is all vaporized when the arc is operating normally. The energy dissipated in the arc is depended upon to keep the envelope hot enough to maintain the enclosed mercury vaporized. If there should be insufficient energy dissipated for this purpose, part of the mercury condenses, the voltage across the arc is reduced, and the light output goes down. With the arc operating at reduced voltage an excess of current is required to bring the light output up to maximum. The ability of the power supply to furnish current may be limited as is the ability of the arc electrodes to carry current, so it is essential that the vapor pressure and the arc voltage be maintained at or near the full values.

For the particular arc lamp used with the control, the arc current is rated at 0.4 amp and the voltage drop at about 270 v. When the arc currents are above about 0.3 amp, there is sufficient energy to keep the voltage up to normal, but as soon as the current drops below this value the energy is insufficient and the voltage and pressure fall. Since the controlled arc has to be capable of operation at currents as low as 50 ma indefinitely, it becomes essential that energy be supplied to the arc from some additional source. Consequently heater coils were added to the structure supporting the arc tube in such a manner that the vapor pressure could be maintained at its full value without regard to the input to the arc itself. These heaters consume about 50 w and can be supplied from any source of power capable of delivering about 50 v and one ampere. The final lamp is shown in Fig. 8.

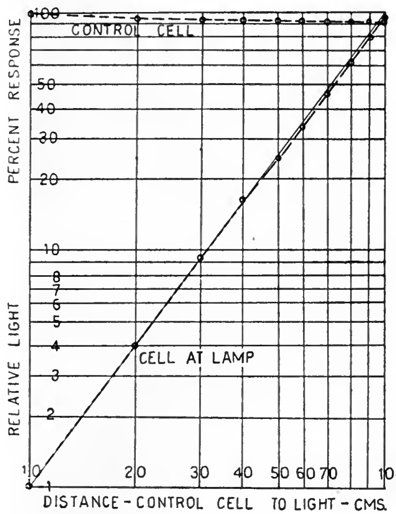


FIG. 7. Performance curves of the new circuits for control of a mercury arc lamp.

MODULATION OF THE ARC LIGHT FOR SOUND TRACK PRINTING

Modulation of the light from the arc is accomplished by introducing the modulating voltage into the circuit so that it will have the same effect upon the light as if it originated in the photocell. The photocell is then free to act as usual and can require the light output to follow quite closely the pattern of the modulation voltage.

Direct electrical modulation of light sources has not received much application because of the lack of a suitable light source. The gas-type lamps originally employed suffered from short life and from poor frequency response at the higher ranges. Modern practice employs steady light sources and mechanical light valves for sound recording.

Our controlled arc overcomes most of the weaknesses that caused rejection of the previous lights. It has a long life with slow deterioration and it modulates well throughout the entire audio spectrum with complete stability and is capable of high percentages of modulation with little distortion.

Fig. 8. The Hanovia modulating arc lamp.

Data were taken to illustrate the performance of the arc when controlled by a modulating voltage. The first curve in Fig. 9 shows the variation of output light with the feedback circuit inoperative. About 75 v were necessary for complete control and there was considerable curvature from maximum to minimum showing that there would be considerable distortion under these conditions. The second curve shows the same data taken with the feedback in normal operation. It shows that more than 300 v are now necessary to produce control and that the light output varies almost directly with the applied voltage. Such a result is exactly what would be expected since it illustrates very well the way in which the inverse feedback limits the disturbance introduced into the circuit, and that with it more than 5 times as much voltage is required to effect the same range of control that was obtained without it.

CONCLUSION

In conclusion, it has been shown that the automatic control with the special high-pressure arc lamp provides the following:

(*1*) A high-intensity concentrated light source, rich in the highly actinic rays, suitable for mounting in a printer.

(*2*) An adjustable light that can be pre-set to any level of intensity and which will stay steady at that level.

(*3*) A light that can be altered from one level of light output to another instantaneously and without an alteration in the quality of the light.

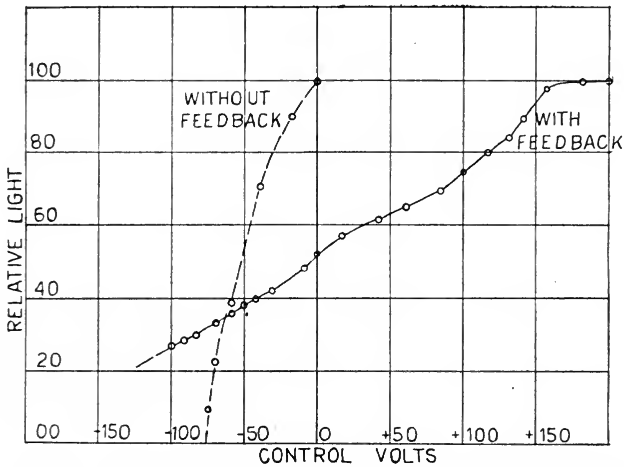


FIG. 9. Performance curves of the Hanovia modulating arc lamp and controls showing the effects of the inverse feedback circuits upon the performance and the control of the light with varying applied control voltages.

(*4*) A light that is adjustable over a range of output of 11 to one to meet the need for this range in printers.

(*5*) A light that can be operated from the usual 60-cycle supply lines without the need for specially regulated power supplies.

(*6*) A light that can be modulated with high fidelity to the control voltage throughout the audio-frequency range and which has stability with long operating life and slow deterioration.

ANECDOTAL HISTORY OF SOUND RECORDING TECHNIQUE

W. A. MUELLER* AND M. RETTINGER**

Summary.—*The purpose of this article is to trace the history of microphones, as used in motion picture production sound recording, and the art of their use. It covers also the development of accessory equipment, such as wind guards, rain guards, microphone booms, etc.*

The history of microphones in sound pictures may be divided into 3 periods. According to the name of the moving element in the unit used at the time, one may thus speak of the condenser, the moving-coil, and the ribbon microphone period. The third period, which is the present, is not too clearly defined, however, by the term "ribbon," since the present microphone is a complex unit consisting of 2 "ribbons" or a "ribbon" and a moving-coil unit.

There is, of course, also a future. Since the developments of the future are always based on the accomplishments of the past, it may serve us to look ahead, and after having enumerated our wants, take inventory to learn how far we have progressed. And since we believe in thoroughness, we went out and gathered all the needs and desires and hopes of practically everyone connected with the recording of sound. This is what we found:

(*1*) The microphone-to-come should be practically invisible.

(*2*) It should be capable of being moved by invisible means.

(*3*) If it must be made of visible materials, it should be no larger and weigh no more than a plum, at most no more than a lemon.

(*4*) It should introduce so little distortion that our present measuring equipment cannot measure it.

(*5*) It should be automatically directional, that is, pick up in each scene only the desired sounds and ignore all others.

(*6*) It should not be affected by wind, rain, and snow.

(*7*) It should record the sounds produced by the weather conditions only when the mixer so desires.

---

* Warner Bros. First National Studios, Burbank, Calif.

** RCA Victor Division, Radio Corporation of America, Hollywood.

The above is truly optimistic and may sound facetious, but it represents the perfect microphone. We doubt, however, whether there is a further cry between the microphone-to-be and the present units than there is between the earliest microphone and what we employ now. Only those who labored in the early days of sound recording can properly appreciate the advancements in this art, and can chuckle when thinking of the bygone days.

Let us therefore visit an early "set," say sometime in the summer of 1929, after the *Jazz Singer* had begun to outline the shape of things to come. There was our matinee idol—dressed to kill and with fire in his eyes. He enters a room, stops, speaks a few lines with head raised slightly, and then walks to a spot designated by chalk marks on the floor, there to deliver the remainder of his lines. The procedure seldom varied. The heroine's deportment suffered similarly. The director suffered, too, dissimilarly.

Why all these stilts, the new-timer may well ask, still conscious perhaps of the finished job his favorite movie star executed the night before. The answer is short, and may be termed "microphonics." It was at the time in no way related to the microphone used on the set. Whatever originated in the microphone—and the sounds from it were hideous—microphonics did not come from there. The generator of microphonics was a vacuum tube—a temperamental wire mesh inside an evacuated glass bulb. It spat and sputtered at the slightest touch or motion—and sometimes apparently for no reason at all.

However, then as now, time marched on. If it was fraught with danger to move the amplifier with its supersensitive vacuum tube, some one said, why not move the condenser microphone attached to the amplifier? The actor would thereby at least be able to turn around, instead of remaining glued to the floor, at the spot marked *X*. Any action was better than none.

Thus, the actor was able to walk about slightly. The increased radius of action was from only 3 to 5 ft—the length of the flexible gooseneck which ran from the amplifier to the microphone. In this way the periodically paralyzed actor began to amble once more, and the director heaved a (small) sigh of relief.

Since this article intends to trace the history of microphones and the art of their use, it may be well not to divorce this unit from its suspension, but to discuss the two side by side, as it were. In this early age of the condenser microphone we have seen that the amplifier was hung in some fashion from the ceiling and the microphone was connected to this electrical equipment by means of a flexible gooseneck. Unfortunately it was standard motion picture practice at that time to photograph the long-shot, the medium-shot, and the close-up simultaneously from several different cameras each housed in a separate booth to prevent the camera noise from disturbing the recorded sound. This procedure frequently showed the microphone in the long-shot, and it became almost an art in itself to hide the unit unobtrusively among the props of the set. In fact, one of the essential talents of a good mixer was his ability to place the microphone so that it would not be visible in the picture but would yet record the dialogue naturally and intelligibly. This, of course, was a serious problem. Concealment of the unit in a vase, inside clocks, ash-trays, or underneath lamp shades frequently resulted in no little damage to the recorded sound because of sound shadows, cavity resonances, and other undesirable conditions created by these stealthy microphone locations. Still, many lines so recorded were surprisingly good—not equal to the best of today perhaps, yet clear enough so as not to detract the listener's attention or to tax his ears unduly.

It may be well at this point to look at the condenser microphone itself a little more closely. Its chief impediment was the noise produced in it by moisture condensation. This condition could bring forth in it the most exasperating crackle of fire—as if a miniature hell had broken loose in it, with the result that every one was tormented accordingly. To relieve this condition the microphone, when not in use, was usually kept in a desiccator filled with calcium chloride to absorb the moisture from the little spit-fire.

Again time marched on. By and by condenser microphones were constructed which were quieter and more trustworthy in their behavior. Also, the microphonic vacuum tube became less microphonic, and before long a heavy type of boom, practicable if primitive, made its appearance on the stage floor of many of the studios. Thus disappeared the many wires and ropes which had been used to suspend the microphone or amplifier, or both, and had reminded one of the strings in a marionette theater, and with them went many a sigh of relief, heaved by the mixer as well as the "grips" and "juicers," not to forget the cameraman.

We have spoken several times of a mixer, taking it for granted that everyone knows what the word means. Technically, the word really has two meanings. So far we have used it only to denote the man who listens to spoken lines over a set of headphones to gain a peremptory impression of the sound recorded on the film. The second meaning of the word is that of the "mixing console," or the small table with its several volume controls and electric meters. To be explicit, however, we shall speak of the mixer only as the man, and write out mixing console when referring to the portable collection of dials and meters.

To the mixer, in the condenser microphone period, were ascribed special functions, some illusory and some real, and he was housed accordingly—usually in a small booth carrying a double pane window. It may be of interest here to quote a paragraph in an early paper on sound recording, written for the purpose of acquainting the personnel of the new art with the most satisfactory manner of recording technique:

"Let us watch the monitor at work. Posted behind the glass windows, he sees the artists, and when they speak, hears them indirectly through the medium of the control loudspeaker. He has, therefore, the illusion of being near them, although actually separated by many thicknesses of glass which insure silence. The scene is repeated. He listens, and communicates his impressions by microphone and loudspeaker to the director. He points out any crackling noises or unpleasant intonations, increases or decreases the sound intensity, modifies the orientation of the microphones, and indicates any acoustic anomalies produced. His control, which is exercised through the medium of a microphone, is much more critical than that of the director in the studio."

This was of yore. Today the mixer sits with the director behind the cameras, listening to the recorded dialogue by means of ear phones while his expert fingers move the volume dials on his mixing console. The microphone and microphone boom have been improved to such an extent that the director is no longer hampered in any way as regards the movement of the actors. He stages the scenes naturally, knowing that the mixer will be able to get good sound pickup regardless of how complicated the shot is. The mixer has become more of a consultant to the director on the mood, tempo, and loudness of the lines spoken by the actor.

Comes now the era of the moving-coil and moving-conductor microphone. These units could be divorced from their associated amplifiers by 50 ft or more of cable and increased the radius of action manifold. Now the actors could wander about at will again and the chalk marks were erased from the floor. The microphones, moreover, were attractively curvilinear, as if to validate the modern artist's slogan that "form follows function."

As the art of microphone construction advanced, so did the art of microphone boom manufacture. Booms were built which were small marvels of mechanical ingenuity, with telescoping duralumin arms and noiselessly controlled swivel arrangements. They rested on rubber-tired wheels, and could be swung about and raised and lowered and made nary a sound. Another milestone has been removed from the road which was apparently being traversed with seven-league boots.

But as most roads, so this one, too, it was found, had its turns and encumbrances. The early sound pictures were all made in special soundproof stages until one producer presented "the first outdoor talking picture." Then sound pictures moved to the desert, the mountains, and the seashore, and many new problems were presented for solution to the sound engineers. One of the worst of these was wind noise which sounded through the microphone like distant artillery fire instead of a gentle zephyr.

Early attempts to reduce the undesirable wind noises on exterior sets consisted essentially of wrapping one or more layers of cloth around the microphone. This, of course, made for greatly distorted and very unnatural sound which was barely intelligible. Still, it gave the picture some semblance of realism, and was better than no sound at all. Soon wind screens were made as an attachable device—crude in form and primitive in execution, but superior to the miniature gunny sacks or handkerchiefs used before. As covering for the metal skeleton a variety of cloths were employed—voiles, silk, cheesecloth, and even burlap—usually applied to the outside of the screen.

When rain and snow scenes were to be made, a protective device known as rain screen was attached to the microphone. It consisted chiefly of, first, a fine mesh metal screen to break the drop into smaller particles, second, a layer of felt below the metal mesh onto which these small particles could drop without a sound, and third, underneath the felt a layer of oilcloth or other material through which water could not penetrate. This device is still used extensively in the industry.

The wind screens of today, however, are finished pieces of aluminum handicraft, easily attachable, and well rounded to avoid any whistling effect. They are still large, however, and not infrequently will throw an annoying shadow. But who can judge their future size without judging the size of the future microphone at the same time? There is a relationship between the two, and as the microphone becomes smaller, the wind screen may contract likewise.

Comes now the third period in our microphone history—that of the ribbon unit. For a long time it has been felt that if a microphone could be constructed which would record only sound coming from a certain direction and ignore sound arriving from other directions, many unwanted sounds, such as those from motor-driven cameras, arc lamps, camera "dollies," and associated equipment in motion on the set during a scene, could be suppressed.

There was, of course, nothing new in the idea of constructing a directional sound pickup device, as testified by the fact that so-called parabolic sound concentrators had been used in the field fairly early. Their drawbacks lay in their large size, heavy construction, difficulty of operation, and the fact that they exhibited numerous and sharp resonances which marred the quality of the recorded sound in no minor manner. For special operations, however, where intelligibility or naturalness of speech could to a degree be sacrificed, they proved very valuable, and may occasionally still be seen. Indeed, as far as the construction of a device is concerned which can exhibit an extremely narrow angle of pickup, the parabolic sound concentrator has no rival, as shown by its former use as an aircraft detector.

Credit for building a unidirectional microphone which could be suspended from a boom goes to three men—Olson, Weinberger, and Massa—who described such an instrument in the *Journal of the Acoustical Society* in October, 1933. But here as elsewhere it was a far step between the first model and the present unit. Suffice it to say that the early microphones were so large and heavy that few of them were used regularly on production. Indeed, it has been only during the last 3 years that this type of microphone, variously known as the unidirectional or cardioid, has been employed extensively by the industry. It may shrink further and become still lighter—and who can tell but that in a few years it may be the size of a lemon, and but a few years further hence, the size of a plum? The engineer has devious ways his plans to achieve.

A NEW MEDIUM FOR THE PRODUCTION OF VANDYKES*

L. S. TRIMBLE**

Summary.—*As the result of Army complaints on the printing quality of Vandykes, or brown line print master negatives, aircraft companies have spent considerable time and effort in expensive tracing heavy-up work.*

Lockheed has specified and had prepared a new and different type of Vandyke paper having sufficient latitude and contrast to produce acceptable prints from combination pencil and ink line tracings. The paper carries a slow photographic emulsion, is processed on the standard blueprint machines under normal operating conditions, and can be furnished at the approximate cost of the present Vandyke paper.

In order to speed production, it is customary for war plants to prepare direct pencil drawings of parts or structures on a thin tracing paper suitable for use in blueprint reproduction. With the extended distribution of war materials, it became necessary for the Armed Forces to prepare copies of certain of these prints. Specifications called for the preparation of a master negative as a Vandyke, suitable for use in the contact printing of blue line positives.

The method of preparing Vandykes, or master negatives of tracings for subsequent blue line reproduction, involves the following:

(*1*) The original drawing or tracing is prepared with pencil on tracing paper. If the lines are sufficiently heavy, a Vandyke can be made by direct contact printing, however, a copy cloth photographic-type positive is often made from this tracing to gain contrast, minimize spots and dirt, and provide a durable record for use in the Engineering Department. This print is often corrected with either ink or pencil lines and sometimes both.

(*2*) A Vandyke negative is made from the copy cloth positive. The Vandyke consists of a pretransparentized 100 per cent rag, 12–16-lb paper base coated with silver salts and suitable halide acceptors such that following exposure to light and treatment in a sodium thiosulfate solution, the exposed sections are converted to brown silver or silver sulfide.

A print made in the above manner from a copy cloth bearing ink and pencil corrections fails to reproduce all lines sufficiently different

---

* Presented Oct. 17, 1944, at the Technical Conference in New York.

** Lockheed Aircraft Corporation, Burbank, Calif.

from the background so that acceptable blue line prints can be made. The problem is well illustrated by the first 2 figures circulated by the Engineering Department.

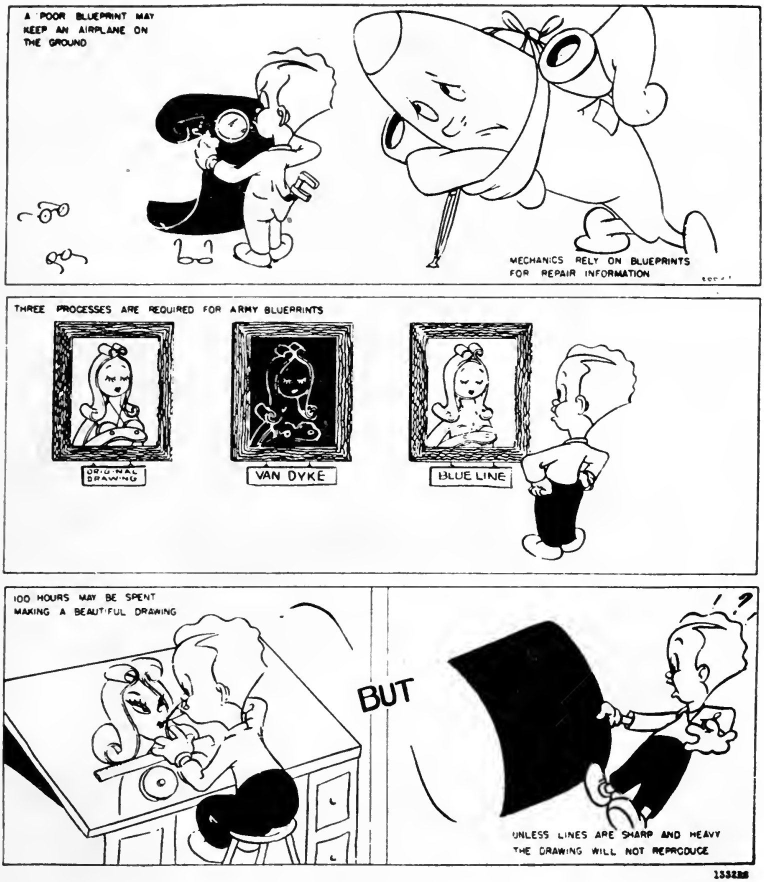


FIG. 1.

The first efforts of Research were directed toward the development of an improved type of drafting pencil to more closely duplicate the quality of ink lines. The immediate results of this work were negative. Attention was then directed toward utilization of chemical and photographic principles in the specification of a Vandyke paper of such quality that the backlog of combination ink, silver, and pencil line tracings could be adequately reproduced without requiring heavy-up work.

To review briefly the principles governing reproduction in light-sensitive materials, it will be recalled that two men, Hurter and

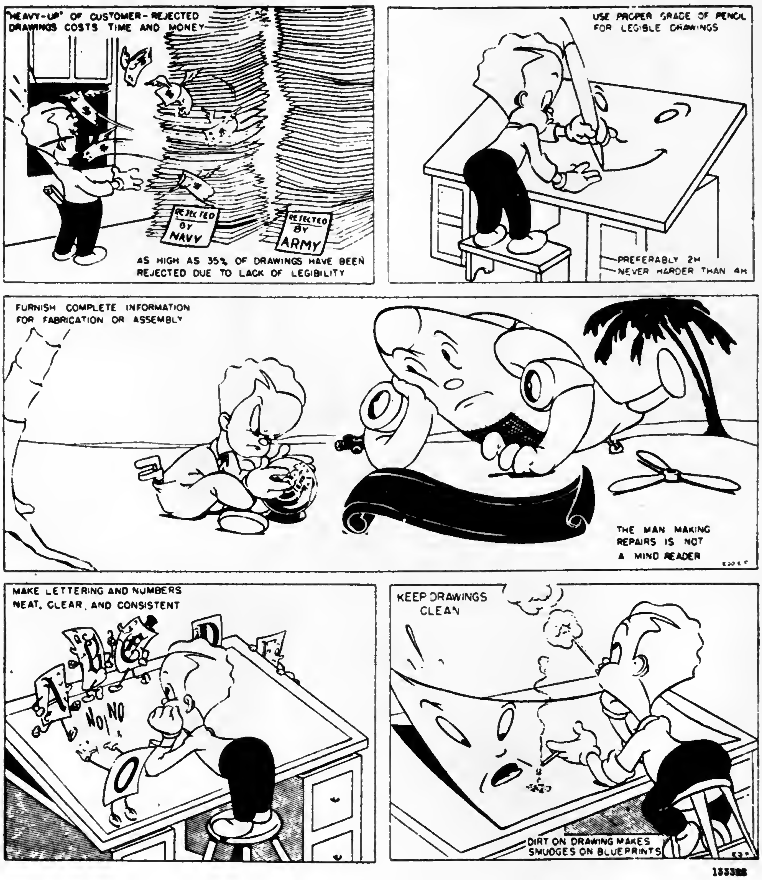


FIG. 2.

Driffield, suggested the following basis for photographic sensitometry:

The *opacity* of a material can be expressed in terms of the incident light intensity required on one side in order to transmit light of unit intensity $= I_0/I$. The *transparency* of a material is a measure of the light getting through, $T = \frac{I}{I_0}$. *Density*, first studied in terms of silver concentration per unit volume, was established as the logarithm to the base ten of the opacity $= \log_{10}\frac{I_0}{I} = \log_{10}\frac{1}{T}$.

The properties of the photographic emulsion as the result of controlled incident energy or exposure, depend upon the treatment of the silver salts during preparation, the gelatin protective colloid, the type of development, and many other factors. Fig. 3 illustrates a typical characteristic curve of a photographic emulsion showing the relation between density as defined above and standardized exposure to white light as obtained on an Eastman sensitometer, type IIb. As this exposure is increased to give a perceptible density for given developing conditions, the density varies almost linearly with exposure in the section known as the toe of the curve. A print in this density region would be underexposed and thin with little difference between densities. Above this toe portion is the straight line portion wherein density varies linearly with log exposure. This is a most useful section of the characteristic curve because the opacities of the silver image are proportional to the exposures produced by the corresponding brightness of the subject. The shoulder section of the curve represents a region of almost constant density with increased exposure. A print in this section would be overexposed and dense with little difference between densities. A study of Fig. 3 will show that the straight line portion of the curve can be represented by the equation:

$$Density = \gamma\ (\log_{10} Exposure + K)$$

The factor γ is a measure of the slope of the straight line portion and is thus a measure of contrast. Contrast is a function of manufactured stock characteristics and color temperature of exposing light, but if the image be placed in the region of correct exposure, contrast can be altered by development. The length of the straight line portion is termed the latitude of the stock and again is a function of manufacture, principally emulsion thickness. The ratio of densities in the region of correct exposure, then, is determined by subject contrast; the differences between densities are determined by development. It is common in the photographic industry to utilize these principles of sensitometry in controlling the speeds, latitudes, and contrasts of photographic materials.

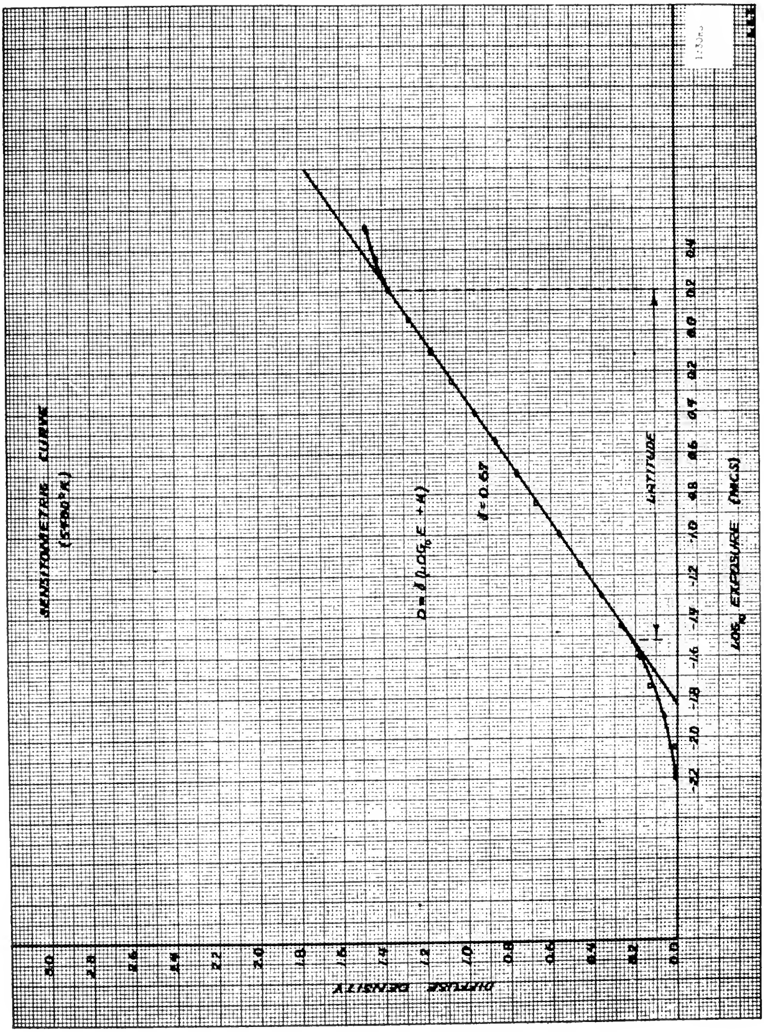


FIG. 3. A typical sensitometric curve.

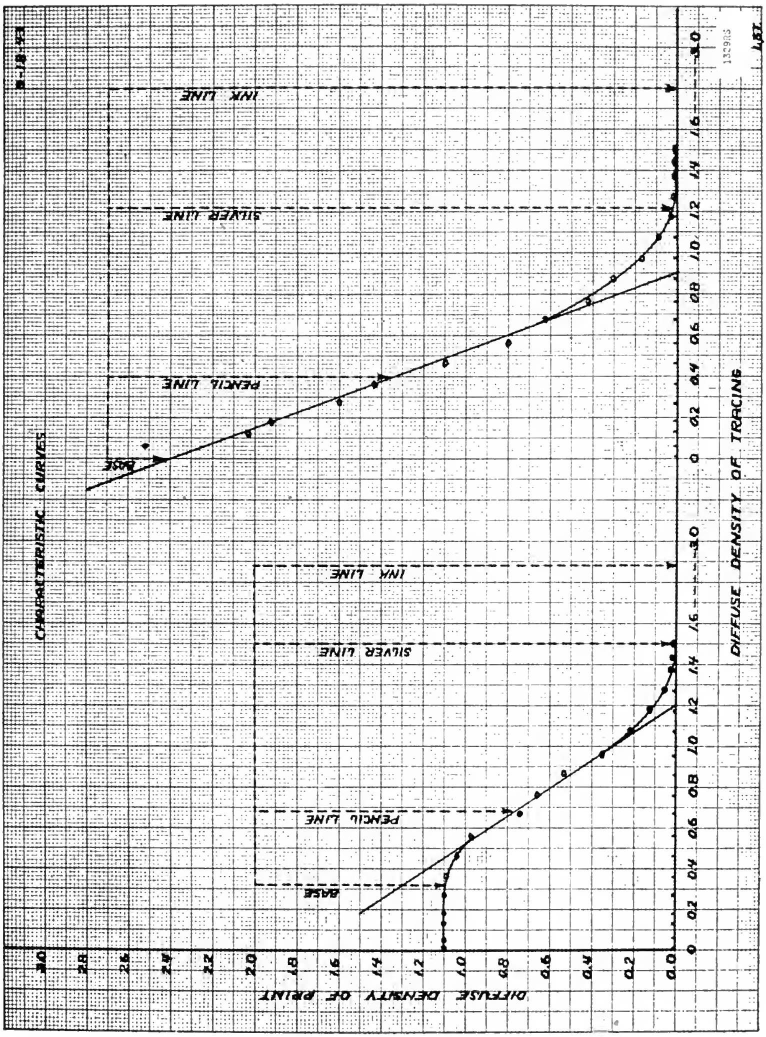


FIG. 4. Characteristic curves of Vandyke and photographic paper.

From these fundamentals it is immediately evident that if a stock had sufficient latitude it would be possible to print the heavy ink lines, the light pencil lines, and the thin base to produce definite density ratios. If, through contrast, sufficient density difference between pencil line and background be available, then acceptable blue line prints could be made.

The vendor of the present Vandyke paper has been unable to supply either greater latitude or higher contrast paper. Chemical intensifi-

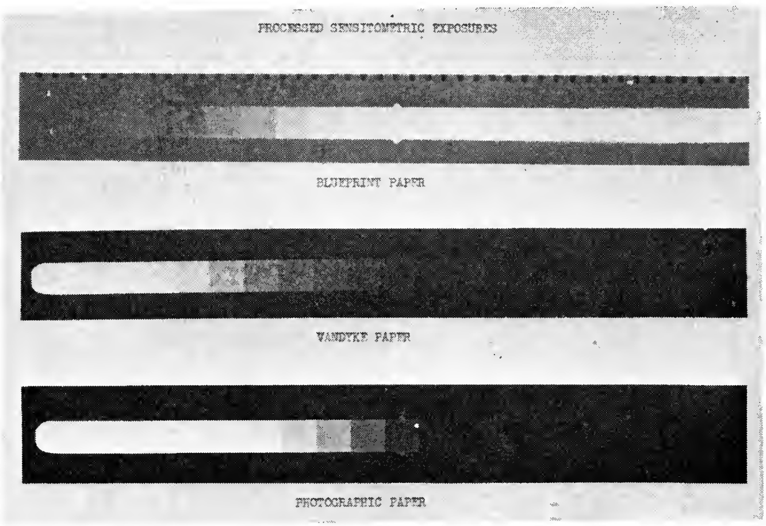


FIG. 5. Processed sensitometric exposures.

cation of this Vandyke image after processing, while possible, was considered impractical.

In order to determine the density range for reproduction, the diffuse transmission densities of the lines of a typical copy cloth were determined on a Capstaff densitometer, and are listed substracting the cloth or base density of 0.38. Typical values are as follows:

Cloth Base	0.00
Ink	2.56
Silver	1.22
Pencil	0.40

The investigation of photographic paper in comparison with Vandyke paper disclosed several interesting facts concerning reproduction of these density differences.

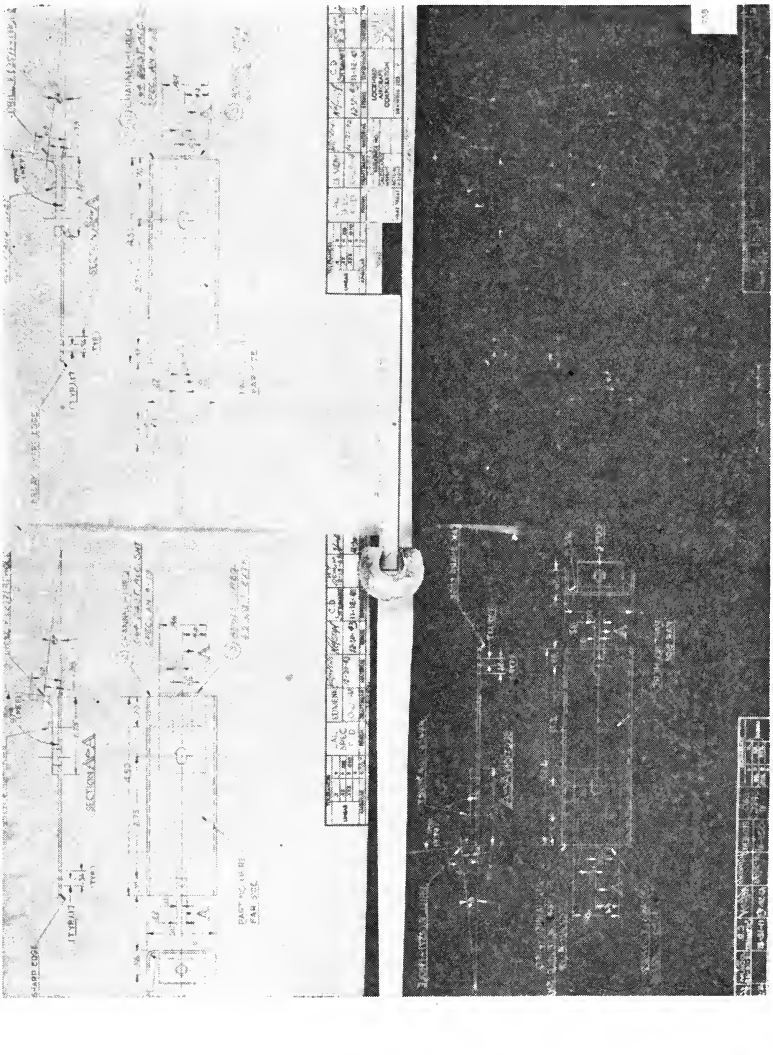


FIG. 6. Relative reproduction quality.

A sensitometric-type exposure was made on the Vandyke paper under processing machine conditions, a similar exposure was made on

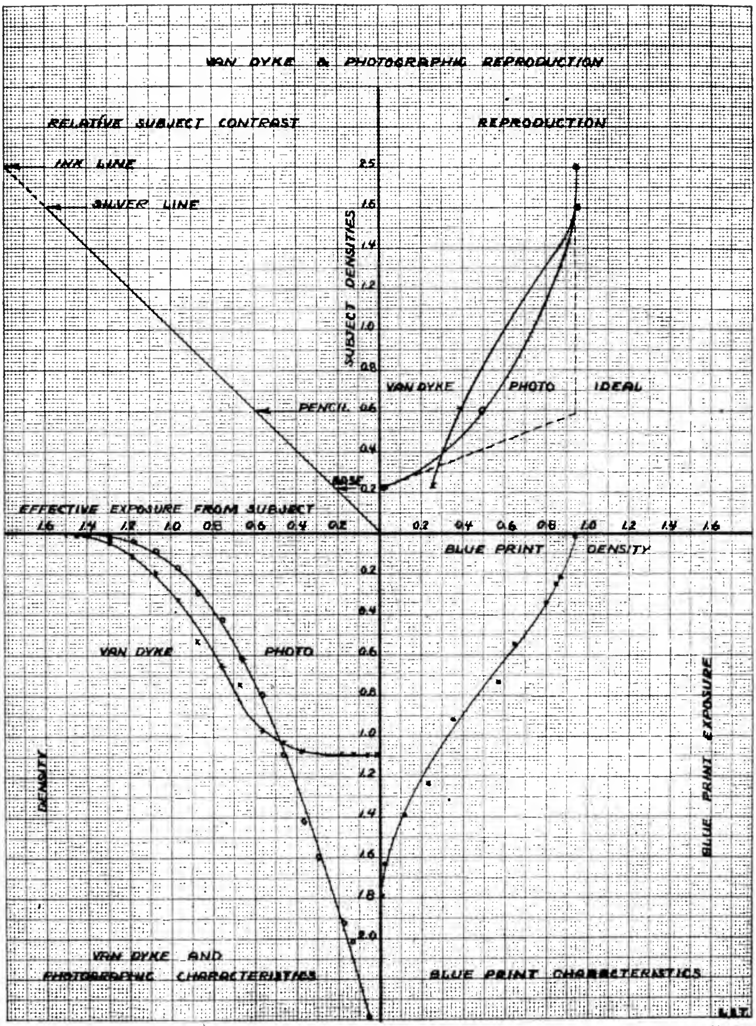


FIG. 7. Graphic reproduction summary.

a 12-lb base photographic paper prepared by the vendor at the request of Research. The diffuse densities of the processed tests were determined and plotted against the corresponding log exposure values. Fig. 4 shows the characteristic curves for the 2 papers shown in Fig. 5. The print density is plotted against the relative exposures obtained by printing through the densities of Fig. 3. It can be seen that if the base or clear sections of the copy cloth are printed to maximum density in each case, then the resulting print density differences are:

	Vandyke	Photo
Between background and pencil lines	0.34	1.02
Between background and silver lines	1.10	2.36
Between background and ink lines	1.10	2.36

It is evident then that using this photographic paper there is a density difference between background and pencil lines of 1.02, or 3 times the density difference available using Vandyke paper. Likewise, because of greater contrast, the maximum density of the photographic paper background compared to a white line is 2.36 compared to 1.10 for the Vandyke paper. This, of course, will result not only in better Vandykes but also in better blue line prints because slower printing speeds can be used without causing exposure through the background. The prints in Fig. 6 were made from a tracing rejected by the inspector. The two on the right represent the best Vandyke negative available from the pencil tracing and the best blue line print that could be made therefrom. The corresponding photographic Vandyke and positive blue line print are shown on the left. It can easily be seen that an acceptable print is available.

A graphic summary of this type of reproduction is shown in Fig. 7. The upper left quadrant represents the range of subject contrast encountered in a typical tracing. The characteristic curves of the Vandyke and photographic papers are shown in the lower left quadrant. Light passing through these densities records on the blueprint paper as shown by its characteristic curve in the lower right quadrant. Although reproduction of the original tracing is sufficient, it is highly desirable to present all lines of maximum density on a clear background. This condition is illustrated by the dotted line in the upper right quadrant. By tracing the subject brightness or effective exposure of any point through 270 degrees to compare initial and final densities, it can be seen that the silver and ink lines record to reproduce maximum blue line density whereas the pencil line is about half maximum density. The greatest difference, however, is noticeable between the background and pencil line densities; in the case of the Vandyke, the density difference is 0.12; on the photographic paper it is 0.50. It can readily be seen that the master negative density differences which control the extent of blue line printing can be increased fourfold by the use of photographic paper.

Although certain slight modifications of the submitted paper are being requested, very pleasing results have been obtained with a photographic emulsion on a 12-lb base which, although not pre-transparentized, is characterized by the same printing speed as brown line or Vandyke paper. The material is quite safe to reasonable use under incandescent illumination; it will fog within a few seconds under fluorescent lights. The image develops within the first 15 sec of the 30-sec development in *D-72*. There is no appreciable gain in density or contrast with prolonged development. Hardening hypo fixes the paper within 90 sec; this is followed by a 2-min wash and normal drying. The cost is comparable to that of the present Vandyke paper.

West Coast aircraft plants have evidenced considerable interest in this new product developed by Research to solve a Lockheed problem. A material capable of the reproduction discussed above and supplied at a price comparable to current brown line papers will have universal application in the blueprint and photo-sensitive reproduction industry.

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

26 (Apr., 1945), No. 4

An All-Friction Drive for Developing Machines (p. 122) — W. G. C. Bosco

26 (May, 1945), No. 5

The Adel Color Camera and Surgiscope (p. 152) — W. G. C. Bosco

Television and Motion Pictures (p. 158) — R. Hubbell

Post-War Motion Pictures (p. 160) — E. Goodman

26 (June, 1945), No. 6

A Method of Film Conservation in Motion Picture Photography, Processing and Reproduction (p. 188) — N. V. Mardovan

Harman Unveils News Animaction Unit (p. 190) — W. G. C. Bosco

Kine-Micrography in Biological Research (p. 192) — R. McV. Weston

The Television Camera (p. 193) — R. Hubbell

Movement in Movies (p. 194) — E. Goodman

New Repeating Flash Tube for Night Aerial Photography (p. 208)

Better Management (*Sec. of* **The Exhibitor**)

8 (May, 1945), No. 5

Air Sterilization with Ultraviolet Light Will Give Theaters True Air Conditioning (p. 5) — W. A. Whitney

8 (June, 1945, No. 6)

Transmission Films Added to Projection Lenses Promise Clearer, Reflectionless Screen Images (p. 5) — W. A. Whitney

British Kinematograph Society, Journal

8 (Jan.–Mar., 1945), No. 1

Future Technical Progress in the Film Industry (p. 2) — A. G. D. West

Kine-Micrography in Biological Research (p. 8) — R. McV. Weston

X-ray Kinematography (p. 9)

Operational Kinematography in the R. A. F. (p. 10) — Moyna

The Work of the National Film Library (p. 13) — E. Lindgren

Communications

25 (Mar., 1945), No. 3

A Television Studio Installation Designed for Research and Instruction (p. 33) — A. Preisman

Electronic Engineering		
	17 (Apr., 1945), No. 206	
Scanning Systems for Colour Television (p. 456)		L. C. Jesty
Electronic Industries		
	4 (Apr., 1945), No. 4	
Multi-Channel Sound Recording on Film (p. 92)		
RCA Reveals Projection Television (p. 95)		
DC Picture Transfer (p. 106)		H. N. Kozanowski
	4 (June, 1945), No. 6	
DuMont's Projection Television (p. 97)		
International Photographer		
	17 (Mar., 1945), No. 2	
The Television Cameraman (p. 11)		W. Bluemel
Specifications for Photographic Flash Lamps (p. 22)		R. E. Farnham
Television Topics (p. 24)		W. S. Stewart
	17 (Apr., 1945), No. 3	
The Garutso Optical Balance (p. 13)		D. M. Morandini
Columbia's Still Laboratory (p. 15)		D. Christie
	17 (May, 1945), No. 4	
Pal's Pals (Puppets) (p. 7)		R. Ravenscroft
Television Topics (p. 23)		W. S. Stewart
International Projectionist		
	20 (Mar., 1945), No. 3	
The Operation and Maintenance of a Popular 16-Mm Projector (p. 7)		A. Nadell
Projection Angle Rule (p. 10)		J. G. Jackson
Proper Operation of Projection Arc Lamps (p. 12)		R. O'Toole
Projectionists' Course on Basic Radio and Television—Pt. 9 (p. 13)		M. Berinsky
	20 (Apr., 1945), No. 4	
Step-by-Step Analysis of a 16-Mm Amplifier (p. 7)		A. Nadell
Design of a Sound-Level Indicator (p. 10)		H. W. Hastings-Hodgkins
Projectionists' Course on Basic Radio and Television—Pt. 10 (p. 18)		M. Berinsky
	20 (May, 1945), No. 5	
Technical Problems of Arc Lamp Design (p. 7)		H. Cricks
Providing Auxiliary Sound Requirements for Motion Picture Theaters (p. 9)		H. B. Sellwood
Television Developments (p. 16)		J. Frank, Jr.
Projectionists' Course on Basic Radio and Television—Pt. 11 (p. 18)		M. Berinsky
Television		
	2 (May, 1945), No. 4	
Video Lighting Problems (p. 4)		W. Miner
Television Station Design (p. 7)		

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION MEETINGS

Dr. A. F. Turner of the Scientific Bureau of the Bausch and Lomb Optical Company, Rochester, N. Y., addressed members and guests of the Atlantic Coast Section of the Society at the meeting on May 23. Dr. Turner, long associated with the development of nonreflecting films, spoke on "Performance of Coated Lenses." The paper covered in a popular manner the optical principles involved in the action of the nonreflecting films, the manner in which they are deposited commercially, and the results to be expected from them.

One of the most interesting demonstrations given by Dr. Turner in the course of his talk involved the transmission of an image through a series of uncoated glass plates as well as through a similar series of coated glass plates. The effect of coating was clearly shown by the brighter image obtained and by the absence of ghosts, which were clearly visible in the transmission through the uncoated plates.

The meeting, held in the *Roof Garden* of the Hotel Pennsylvania, New York, was attended by approximately 150.

High-speed motion picture photography was the concluding subject in the Spring 1945 series of Atlantic Coast Section meetings, which was held on June 13 in the *Georgian Room* of the Hotel Pennsylvania. The speaker was Henry M. Lester, cinephotographer of New York, whose topic was "Continuous Flash Lighting: An Improved Source for High-Speed Motion Picture Photography."

High-speed motion picture cameras, capable of taking pictures on continuously moving film at the rate of upward of 3000 frames per sec, produce individual exposures of the order of $^1/_{15,000}$ sec and less. Since the actual time during which high-intensity illumination is required seldom exceeds one second, the light of certain Photoflash lamps will provide satisfactory illumination for this purpose, when such lamps are operated in suitably designed equipment.

Mr. Lester demonstrated his continuous flash lighting unit which provides adequate illumination for both black-and-white and color high-speed motion picture photography, and showed motion pictures of the equipment in action.

C. R. Keith, chairman of the Section, announced that the Fall series of meetings would cover a wide range of subjects of current interest, the first of which is tentatively scheduled for September 19.

HOLLYWOOD TECHNICAL CONFERENCE

The 57th Semi-Annual Technical Conference held at the Hollywood-Roosevelt Hotel, Hollywood, California, on May 14–18, inclusive, was one of the most successful meetings ever held by the Society. The quality of the papers presented and the wide range of topics discussed were responsible for drawing a large local attendance during the 5-day meeting.

It was decided before the Conference to withhold distribution of the usual tentative program in order not to promote out-of-town attendance, in cooperation with governmental regulations on transportation and hotel accommodations. It is felt, however, that many members of the Society would be interested in having a list of the papers presented. The Board of Editors therefore is publishing in this issue of the JOURNAL the complete program as followed.

In order to make the information contained in these papers available to members as soon as possible, the Board of Editors is planning to publish this material as early as manuscripts on hand permit.

Program

Monday, May 14, 1945

12:30 p.m. *California Room:* **SMPE V-E Luncheon,** for members and guests. D. E. HYNDMAN, President of the Society, presided.

Address of Welcome: WALTER WANGER, President, Academy of Motion Picture Arts and Sciences.

Guest Soloist: OLGA SAN JUAN, Paramount Singer and Dancer.

2:00 p.m. *Studio Lounge:* **Afternoon Session.**

L. L. Ryder, *Chairman*

J. G. Frayne, *Vice-Chairman*

Session opened with a 35-mm motion picture short.

Report of Convention Vice-President, W. C. Kunzmann.

"Engineering Committee Reports on Laboratory Practice, Non-Theatrical Equipment, Preservation of Film, Television, Standards, Theater Engineering," by J. A. Maurer, Engineering Vice-President, SMPE.

"Wave Propagation and Outdoor Field Tests of a Loudspeaker System," by F. L. Hopper and R. C. Moody, Western Electric Co., Inc., Hollywood, Calif.

"Film Noise Spotter," by J. P. Corcoran, Twentieth Century-Fox Film Corp., Beverly Hills, Calif.

"Reverberation Chambers for Rerecording," by M. Rettinger, RCA Victor Division, Radio Corporation of America, and James Stewart, RKO Radio Pictures, Hollywood, Calif.

"The Comparison of Beam Power and Triode Tubes Used in Power Amplifiers for Driving Loudspeakers," by J. K. Hilliard, Altec Lansing Corp., Hollywood, Calif.

"A New Carbon for Increased Light in Studio and Theater Projection," by M. T. Jones, R. J. Zavesky, W. W. Lozier, National Carbon Company, Fostoria, Ohio.

"Airborne Sound Recorders," by G. C. Brubaker, Memovox, Inc., Beverly Hills, Calif.

A demonstration was given.

8:00 p.m. *Studio Lounge:* **Evening Session.**

K. F. Morgan, *Chairman*

C. R. Keith, *Vice-Chairman*

Session opened with a 35-mm motion picture short.

"Progress Report on War Standards for Photography and Motion Pictures," by J. W. McNair, American Standards Association, New York.

"Push-Pull FM Circuit and Its Application to Vibratory Systems," by Alexis Badmaieff, RCA Victor Division, Radio Corporation of America, Hollywood, Calif.

"Cinemicrography in Biological Research," by R. McV. Weston, Secretary, Association for Scientific Photography, Houndwood, England.

"An Integrating Voltmeter for Measurement of Fluctuating Voltages," by Harold Haynes, RCA Victor Division, Radio Corporation of America, Indianapolis, Ind.

A demonstration film was presented.

"A New Two-Way Theater Loudspeaker System," by J. B. Lansing and J. K. Hilliard, Altec Lansing Corp., Hollywood, Calif.

"A Public Address and Sound Re-Enforcement System Using the Duplex Loudspeaker," by J. B. Lansing, Altec Lansing Corp., Hollywood, Calif.

Tuesday, May 15, 1945

Open Morning.

2:00 p.m. *Studio Lounge:* **Afternoon Session.**

W. V. Wolfe, *Chairman*

N. L. Simmons, *Vice-Chairman*

Session opened with a 35-mm motion picture short.

"A Multisection Rerecording Equalizer," by W. L. Thayer, Sound Dept., Paramount Pictures, Inc., Hollywood, Calif.

"A Three-Band Variable Equalizer," by L. D. Grignon, Twentieth Century-Fox Film Corp., Beverly Hills, Calif.

"Mathematical Analysis of a Recorder Film Drive Filter System," by J. R. Alburger, Electrical Research Products Division, Western Electric Co., Inc., Hollywood, Calif.

"Improved Film Recording Channels," by Dr. C. R. Daily, Sound Dept., Paramount Pictures, Inc., Hollywood, Calif.

"Organizing 16-Mm Production," by Lloyd Thompson, The Calvin Company, Kansas City, Mo.

"Variable-Area Release from Variable-Density Original Sound Track," by J. P. Livadary and S. J. Twining, Columbia Pictures Corp., Hollywood, Calif.

"Automatic Recording of Photographic Densities," by J. G. Frayne and G. R. Crane, Electrical Research Products Division, Western Electric Co., Inc., Hollywood, Calif.

8:00 p.m. *Studio Lounge:* **Evening Session.**

Herbert Griffin, *Chairman*

G. E. Sawyer, *Vice-Chairman*

Session opened with a 35-mm motion picture short.

"The Projection Life of Film," by R. H. Talbot, Eastman Kodak Co., Kodak Park, Rochester, N. Y.

"Report of the Subcommittee on Projection Sprocket Design," by J. A. Maurer, Engineering Vice-President, SMPE.

"Television vs. Motion Picture Practices," by Klaus Landsberg, Director of Television, Station W6XYZ, Television Productions, Inc., Hollywood, Calif.

"Film—The Backbone of Television Programming," by R. B. Austrian, Executive Vice-President, RKO Television Corp., New York.

Wednesday, May 16, 1945

Open Morning.

2:00 p.m. *Studio Lounge:* **Afternoon Session.**

H. W. Moyse, *Chairman*

S. P. Solow, *Vice-Chairman*

Session opened with a 35-mm motion picture short.

"Positive Vari-Focal View-Finder for Motion Picture Cameras," Dr. F. G. Back, Research and Development Laboratory, New York.

The following 5 papers were presented by members of the U. S. Army Signal Corps Photographic Center, Long Island City, N. Y.:

"The Psychological and Technical Considerations Employed in the Bucky Sound Reproduction and Public Address System," by Lieut. P. A. Bucky.

"An Optical Cueing Device for Disk Playback," by Major G. C. Misener.

"Army Film Distribution and Exhibition," by Major R. A. Kissack, Jr.

A demonstration film was presented.

"A System of Lens Stop Calibration by Transmission," by Emmanuel Berlant.

A demonstration was presented.

"Development of Two Automatic Follow-Focusing Devices for Use in Cinematography," by Capt. J. T. Strohm and Capt. W. G. Heckler.

A demonstration film was presented.

5:30 p.m. *California Room:* A social hour with the Board of Governors. Invitations were issued to registered members and guests.

Open Evening.

Thursday, May 17, 1945

Open Morning.

2:00 p.m. *Studio Lounge:* **Afternoon Session.**

Emery Huse, *Chairman*

Lt. Comdr. Franklin Hansen, *Vice-Chairman*

Session opened with a 35-mm motion picture short.

"A New Photographic Developer for Picture Negative," by J. R. Alburger, Hollywood, Calif.

"A Note on Chemical Drag Observed with Variable-Density Sound Track," by Dr. D. Meschter, Photo Products Dept., E. I. duPont de Nemours & Co., Inc., Parlin, N. J.

"duPont Fine-Grain Sound Films, Type 232 and 236," by H. W. Moyse, Photo Products Dept., E. I. duPont de Nemours & Co., Hollywood, Calif.

"The Work of the Naval Photographic Services Depot," by Lt. Comdr. F. M. Hearon, Officer-in-Charge, Naval Photographic Services Depot, Hollywood, Calif.

"Colored Trace Oscillographs," by L. S. Trimble and F. W. Bowden, Lockheed Aircraft Corp., Burbank, Calif.

8:00 p.m. *Studio Lounge:* **Evening Session.**

E. A. Williford, *Chairman*

L. E. Clark, *Vice-Chairman*

Session opened with a 35-mm motion picture short.

"Practical Utilization of Monopack Film," by C. G. Clarke, Director of Photography, Twentieth Century-Fox Film Corp., Beverly Hills, Calif.

"The Printing of 16-Mm Kodachrome Duplicates," by R. M. Evans, Research Laboratories, Eastman Kodak Company, Rochester, N. Y.

"Machine Processing of Ansco Color Film," by J. L. Forrest, Ansco, Binghamton, N. Y.

A demonstration film was presented.

Friday, May 18, 1945

Open Morning.

2:00 p.m. *Studio Lounge:* **Afternoon Session.**

W. A. Mueller, *Chairman*

P. E. Brigandi, *Vice-Chairman*

Session opened with a 35-mm motion picture short.

"Orthoscope Lenses," by Hal Huff, H & H Optics, Los Angeles, Calif.

"An Automatic Interlock Switch," by D. J. Bloomberg, Republic Pictures Corp., Studio City, Calif.

"A Discussion of the Acoustical Properties of Fiberglas," by W. M. Rees and R. B. Taylor, Owens-Corning Fiberglas Corp., Toledo, Ohio.

"Flame Retardant Materials for Motion Picture Applications," by Barton Thompson, Engineering Dept., Paramount Pictures, Inc., Hollywood, Calif.

"The Filing and Cataloguing of Motion Picture Film," by C. M. Effinger, Twentieth Century-Fox Film Corp., Beverly Hills, Calif.

"A Small Microphone Boom," by B. F. Ryan and E. H. Smith, Warner Bros. Pictures, Burbank, Calif.

"A Survey of Photo-Template Methods," by Faurest Davis, Ansco, Los Angeles, Calif.

"Power Rectifiers for Studio Lighting," by L. A. Umansky, Industrial Engineering Division, General Electric Co., Schenectady, N. Y.

8:00 p.m. *Walt Disney Theater, Disney Studio, Burbank:* **Evening Session.**
A. M. Gundelfinger, *Chairman*

Session opened with a 35-mm motion picture short.

"The Problem of Amateur Color Photography," by R. M. Evans, Research Laboratories, Eastman Kodak Company, Rochester, N. Y.

This was an hour and forty-five minute semi-popular demonstration lecture on color photography.

Adjournment of 57th Semi-Annual Technical Conference, by D. E. Hyndman, President of the Society.

EMPLOYMENT SERVICE

POSITIONS OPEN

Position open for man or woman with experience in optical instrument design. Position also open for man or woman with experience in lens design or computing. Write for interview. Binswanger and Company, Optics Division, 645 Union Ave., Memphis, Tenn.

Physicist with special training in optics for research on utilization of carbon arcs particularly in projection systems. Apply to Research Laboratory, National Carbon Co., Inc., P. O. Box 6087, Cleveland 1, Ohio.

Designer and engineer experienced in optics, lighting, and microphotography, capable of designing microfilm reading equipment and products related to microfilm industry. Reply to Microstat Corporation, 18 West 48th St., New York 19, N.Y.

Design engineer, experienced in mechanics and optics of motion picture cameras, projectors, and film scanning. Give details. Reply to Mr. John H. Martin, Columbia Broadcasting System, Inc., 485 Madison Ave., New York 22, N.Y.

POSITION WANTED

Sound recording engineer, 16- or 35-mm equipment, studio or location work, single or double system. Free to travel. For details write J. J. K., 354 Ninth Ave., New York 1, N.Y.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 **AUGUST, 1945** **No. 2**

CONTENTS

Indexes to the semi-annual volumes of the Journal are published in the June and December issues. The contents are also indexed in the *Industrial Arts Index* available in public libraries.

JOURNAL

OF THE

SOCIETY of MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA • NEW YORK 1, N.Y. • TEL. PENN. 6 0620

Subscription to nonmembers, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscription or single copies of 15 per cent is allowed to accredited agencies. Order from the Society at address above.
Published monthly at Easton, Pa., by the Society of Motion Picture Engineers, Inc.
Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, Hotel Pennsylvania, New York 1, N. Y.
Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 AUGUST, 1945 No. 2

REPORT OF THE SUBCOMMITTEE ON PROJECTOR SPROCKET DESIGN*

It has long been known that the projection life of film could be increased considerably if the intermittent sprockets used were at least as large or larger than that required to give perfect mesh with the film being driven. It is on this basis that the SMPE standard sprocket was designed.

When this sprocket came into use, however, it was found in some cases that the sprocket wore out faster than the old sprockets and the projector manufacturers were loathe to use them.

It has been suggested, however, that in recent years the average shrinkage of film has considerably decreased and that with hardened and ground sprockets the difficulty of wearing of the sprockets might be avoided. A Subcommittee, therefore, was formed on June 19, 1941, to investigate the matter and bring a recommendation to the Standards Committee.

Approximately a year ago a series of sprockets of different diameters were made by the International Projector Company and were installed in special theaters where they could be observed by M. H. Bennett of the Warner Bros. Theatres and C. F. Horstman of the RKO Radio Pictures Corporation. Other sprockets made by the Century Projector Company have been installed in theaters in Rochester, N. Y., and vicinity. Before the sprockets were installed, careful measurements and photomicrographs of the teeth were made. In every case where a large-size sprocket was used the companion projector was fitted with a new sprocket of 0.935-in. diameter. In a few cases where 3 projectors were used, 2 different large-size sprockets were used and one 0.935-in. sprocket was used.

The original plan was to run some of the sprockets for a year and some for 2 years, examining them for quietness of operation during

* Presented May 15, 1945, at the Technical Conference in Hollywood.

that time. At the end of the period of running the sprockets would be taken out of the projectors, photomicrographed for wear, and then would be used to determine the wearing quality of film on these sprockets.

At the present time 10 or 15 theaters have been supplied with these experimental sprockets and 3 sets of sprockets have been removed and examined. All of the projectors have been watched and the report is that there is no difference in noise or ease of handling the film between any of the sprockets.

TABLE 1

Sample	Runs to Break-Down with Used 0.943-In. Sprocket	Runs to Break-Down with Used 0.935-In. Sprocket
A	1100	540
B	843	517
C	982	540
D	912	491
E	1165	630
F	1374	573
G	1287	566
H	1239	530
I	1665	590
J	1326	603
K	1169	594
L	1746	800

One set of sprockets was removed from the Riviera Theatre in Rochester where it had been in operation for 2 years. In this set the 0.943-in. sprocket shows somewhat less wear than the 0.935-in. sprocket. These 2 sprockets were then put successively on a projection machine and 10 different samples of film were run on both sprockets. The results are shown in Table 1. It will be observed that the large-size sprocket gave approximately double the film life of the smaller one.

A set of 3 sprockets, 0.945-, 0.943-, and 0.935-in., was removed from the RKO 58th Street Theatre in New York, and a similar test run. These results are shown in Table 2. It will be observed that the 0.943-in. sprocket shows somewhat better wear than 0.945-in. and both are considerably better than 0.935-in. sprocket. We have no explanation for the fact that the 0.943-in. sprocket appears better than the 0.945-in. since previous work has indicated that the reverse is generally ture.

TABLE 2

Sample	Runs to Break-Down with Used 0.935-In. Sprocket	Runs to Break-Down with Used 0.943-In. Sprocket	Runs to Break-Down with Used 0.945-In Sprocket
M	517	3216	1086
N	396	1209	579
O	774	2406	1834

Although the Subcommittee had originally intended to run these tests for still another year, it has been suggested that the results to date are conclusive enough to warrant a real effort on the part of the Society to get theaters to use the larger-size sprockets, preferably the 0.943-in. sprocket, in order to conserve film during the present shortage.

E. K. CARVER, *Chairman*

H. BARNETT
M. H. BENNETT
M. R. BOYER
L. W. DAVEE
J. L. FORREST
C. F. HORSTMAN
L. B. ISAAC
H. RUBIN

THE MOTION PICTURE AND INTERNATIONAL ENLIGHTENMENT*

WALTER F. WANGER**

Mr. Hyndman, Ladies, and Gentlemen:

It is a great honor to welcome the Society of Motion Picture Engineers to Hollywood, for I know of no group of men who are advancing the all-important cause of international understanding more effectively than you.

It is a privilege to talk to you because you are scientists and inventors and are not bound by the past but live for the present and the future. *You* realize how communications have changed the thinking of the world in the past 25 years—something many leaders throughout the world do not seem to understand.

Your meeting really should be a part of the World Conference now being held in San Francisco, also—and I can say this being a native of San Francisco—the World Conference should have been held in Hollywood, for no medium has presented ideas more effectively to the people of the world than our motion pictures. And no plan decided upon at the San Francisco Conference can be successful unless it has the support of the masses who therefore must have it presented to them properly. The responsibility to the people does not end here. It goes beyond mere presentation of the basic plan. There must be a continuous flow of information so there will be no lessening of interest on their part. No peace can endure unless the peoples of the earth are informed and enlightened.

We are faced with two concrete problems: How are the millions of people throughout the world going to receive this information and enlightenment, even if we put it on film, and how can we be sure the film inspires courageous thinking in the interest of the people and not controlled thinking in the interest of the few? Plato said, "Without the knowledge of good and evil, the use and excellence of the sciences will be found to have failed us."

The answer to our first question, How the information and enlightenment is to be brought to the masses, is a simple home projector

---

* Presented May 14, 1945, at the opening luncheon, 57th Semi-Annual Technical Conference in Hollywood.

** President, Academy of Motion Picture Arts and Sciences, Hollywood.

that can be manufactured in volume. This one device is needed most urgently if we are to reach the great audiences in China, India, Africa, and our own hinterlands, and would mean more to the world than any of us can realize.

In answering the second question, I should like to quote again from Plato who said, in describing how each human soul before birth drove across heaven in the company of the gods and saw beauty, justice, courage, and the other virtues, that "success in life depends on how far, among the shadows, confusions, and distractions of earth, the soul retains the memory of that vision."

Plato's story is a parable of a *good education*. We who have been dealing in popular entertainment in Hollywood have always glorified beauty which has become known as glamor. We have glorified justice in all our films. Justice has always triumphed. And certainly we have glorified courage. As pictures have continued to be produced their standards have risen as public taste has improved. *You* have made it possible for us to add, first sound, which included speech and music, then color, and these contributions brought about great improvement in all other departments of film-making. To improve standards in a democratic way is to improve the taste of the people so they will continually reject the inferior for the superior.

The answer to the second question is to see to it that the false content of communications will be rejected by a public fortified with knowledge and enlightenment as they will reject control of communications by the selfish and greedy for their own interests.

We are witnessing the beginning of one world.

We can never go backward. Science is moving us too rapidly.

The war has given the motion picture a new stature. It is now recognized by statesmen and educators alike as a great force for human enlightenment, and rightly so. For at last it has become evident that there is no more limitation to the use of film than to the printing press.

The challenge to the makers of motion pictures is great. We must not limit our production to entertainment in its narrowest sense. We must produce documentaries. We must make educational, commercial, training, and experimental films and show them to all the world.

I believe we have enough new blood among us to accept this challenge—if we have your help and enough sense to accept it.

THE PROJECTION LIFE OF FILM*

R. H. TALBOT**

Summary.—*With the present scarcity of raw print stock, there is need for procedures which will substantially increase the useful life of the film at hand. Prints are rendered unserviceable by damage to the perforations, by mutilation of the edges in shipment, and by abrasion of the surfaces.*

The means by which each of these types of film damage can be minimized (and in some cases almost entirely eliminated) will be described. The adoption of only one of these film conservation measures should double the useful life of a print. Universal adoption of all these measures could make possible several hundred bookings of a print.

WEAR LIFE OF MOTION PICTURE POSITIVE FILM

There is no simple answer to the question "How many times can film be run through a projector?" It has been demonstrated many times that whereas one sample of film may become completely unserviceable after relatively few projections, another sample from the same roll of film may still be in serviceable condition after several thousand projections, depending on the conditions of operation.

It is true that there are certain qualities of the film stock itself which influence its wear life. Much could be written on the relation of the physical properties of the film (tensile strength, tear resistance, brittleness, *etc.*) to its durability. This relation, however, is one with which the film manufacturer is primarily concerned. The user of film is more concerned with those factors which greatly influence the wear life of the film he has at hand. This paper deals with some of these factors.

Relationship between Pitch of Sprockets, Pitch of Film, and Film Wear.—If motion picture film were as dimensionally stable as steel, there would be no problem of the relative pitches of film perforations and sprocket teeth; the 2 pitches would always be equal and, consequently, several sprocket teeth would be in contact with the edges of the perforations at the same time. Actually, the pitch

---

* Presented May 15, 1945, at the Technical Conference in Hollywood.

** Eastman Kodak Company, Kodak Park, Rochester 4, N. Y.

of the film perforations is changing more or less continually, owing to the loss of volatile materials and also to the dimensional changes which accompany variations in moisture content of the film. What then should be the pitch of the intermittent sprocket teeth?

The projector manufacturer has several choices in the design of the intermittent sprocket. He may make the pitch of the teeth such that there will be almost perfect mesh between film and sprocket when the film is freshly processed and less and less close mesh as the film shrinks, or he may make the pitch of the teeth such that there will be closer and closer mesh as the film ages. He may even choose a compromise pitch so that the film fits the sprocket best after the film has shrunk a portion of the total amount.

In order to decide which course is the best to follow from the standpoint of film wear, it might be of interest to review the behavior or movement of film on a sprocket in each of the 2 cases, *i. e.*, Case I—The pitch of the film perforations is greater than that of the sprocket teeth; Case II—The pitch of the film perforations is less than that of the sprocket teeth.

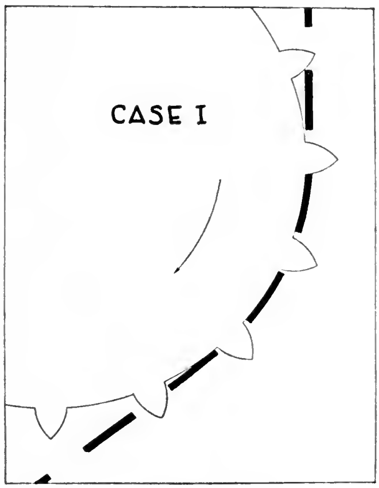


FIG. 1. Action of film on a sprocket when the pitch of the film perforations is greater than the pitch of the sprocket teeth.

Fig. 1 shows the behavior or movement of film on a sprocket when the pitch of the film is greater than that of the sprocket. This was described before the Society in 1923 by J. G. Jones, of the Eastman Kodak Company.[1] Note that the entering tooth strikes the edge of the perforation and shifts the film forward, the film traveling faster than the surface of the sprocket. This wedging-on of the film on the sprocket teeth produces a severe strain on and eventually a tearing of the perforations, and decreases the life of the film. This is the condition which exists today with the 0.935-in. diameter intermittent sprocket which was designed for films of much higher shrinkage than those in use at the present time.

Fig. 2 shows the action of film on a sprocket when the pitch of the film is less than that of the sprocket. Here, the tooth that is about to leave the film does the driving, and the entering tooth engages the film without touching the edge of the perforation. The film is well seated at the base of the tooth when it makes contact with the driving face. Theoretically, this condition should cause less wear on the film than the previous case, in which the pitches of the film and the sprocket are reversed. Actually, experiments show that lower wear may occur on either side of perfect mesh, but, in general, so far as film wear is concerned, it is better to have the pitch of the film less than that of the sprocket rather than greater than that of the sprocket, as is the case today.

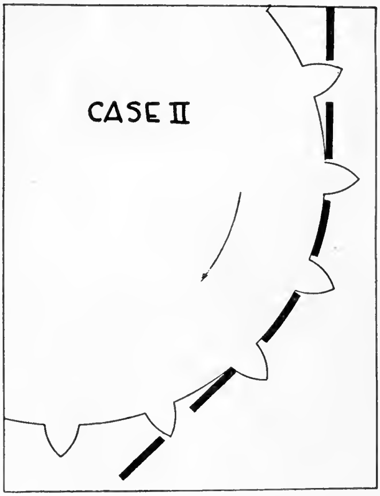


FIG. 2. Action of film on a sprocket when the pitch of the film perforations is less than the pitch of the sprocket teeth.

This fact is illustrated in Fig. 3, which shows graphically the increased number of projections, plotted along the ordinate, as the shrinkage* of the film, plotted along the abscissa, causes the pitch of the film to become equal to, or slightly less than, the pitch of the intermittent sprocket. The shrinkage of film necessary to give perfect mesh with a 0.935-in. sprocket is illustrated by the dotted line. All points to the left of this line represent Case I, in which the pitch of the film is greater than that of the sprocket, and all points to the right of the dotted line represent Case II, in which the pitch of the film is less than that of the sprocket.

The actual number of projections required to produce complete breakdown of the film at the various film shrinkages will vary widely with machine conditions and the manner of operation. The maximum may occur under some conditions at several hundred to one

* The values along the abscissa are expressed as "per cent shrinkage" of the film, for convenience. Since it would be impossible to obtain shrinkages of such great range with the present motion picture films, many of the samples were perforated less than standard pitch on specially designed equipment in order to simulate films having these different shrinkages.

thousand passages through the projector; under still better conditions, it may occur at several thousand passages. Cases have been noted in which the maximum occurred at 22,000 passages. These figures were obtained by projecting short loops of film continuously on a simplified machine under carefully controlled conditions. The number of projections therefore are probably higher than can be obtained in practice because of the carefully controlled conditions under which such tests must be run. The main point is that there is a

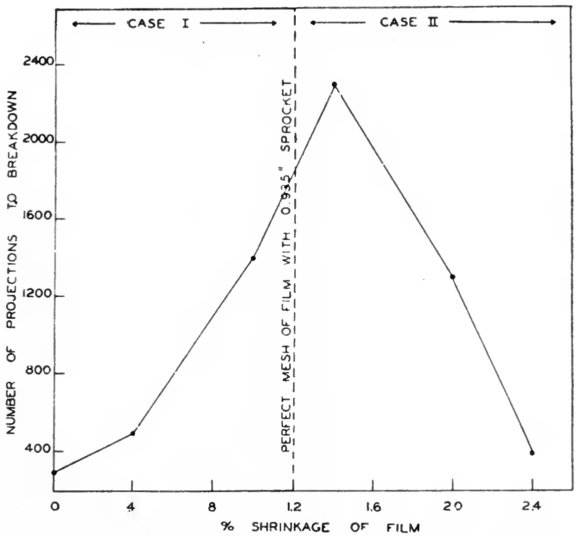


FIG. 3. Relationship between the pitch of the film and the number of projections necessary to produce film breakdown, using an 0.935-in. intermittent sprocket.

maximum and that this maximum occurs on a 0.935-in. sprocket at a shrinkage of film far greater than exists in any present-day motion picture positive film. (The amount of shrinkage of most motion picture positive film lies between 0.0 and 0.6 per cent during its normal projection life.)

Theoretically, the film is in perfect mesh with the 0.935-in. sprocket when it has a shrinkage of 1.2 per cent, and one might expect that the maximum should occur at this point. Frequently, it does occur close to this point, as indicated in Fig. 3. However, it occurs often at a point well beyond the point of perfect mesh, as illustrated by Fig. 4. The reason for the failure of the maximum passages to occur at the point of perfect mesh has not been clearly established. The following is offered as a possible explanation: In Case I, in which the pitch of the film is greater than that of the sprocket, the film wedges on to the sprocket tooth, the film traveling faster than the circumference of the sprocket. Consequently, all of the driving action is accomplished by the sprocket teeth. In Case II, in which the pitch of the film is less than that of the sprocket, the circumference of the sprocket travels faster than the surface of the film. In this case, a considerable portion of the driving action is accomplished by contact

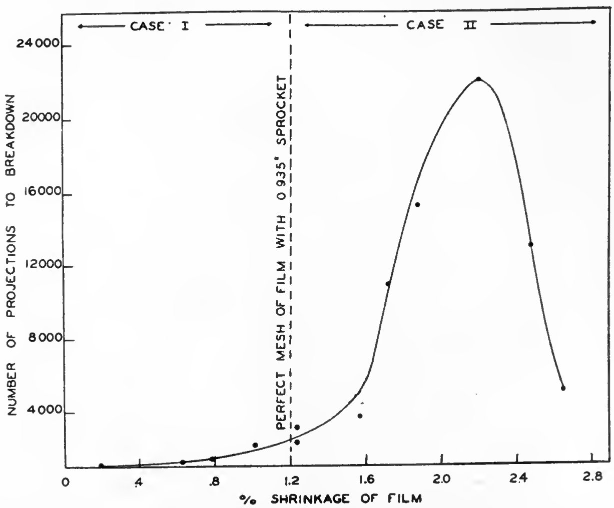


FIG. 4. Same as Fig. 3 with the exception that the maximum number of projections does not occur at or near the point of perfect mesh of film and sprocket.

along the circumference of the sprocket as well as by the sprocket teeth, thus causing the number of passages to increase to a certain point as the pitch of the film becomes less than that of the sprocket.

Likewise, the failure of the maximum number of projections to occur at the calculated point of perfect mesh can be explained by the stretching of the film at the point of impact. If the film stretches upon impact of the sprocket tooth, and this appears to be a reasonable assumption, the effective pitch is greater than the calculated or measured pitch. Therefore, to obtain the optimum projections, the pitch of the film should be less than that required to give perfect mesh.

There is another and perhaps more satisfactory manner in which data of this type can be presented graphically. Since it is not the actual pitch of the sprocket and of the film, but only the difference between them which matters, we may express this difference graphically along the abscissa as the per cent deviation of the film from the pitch of the sprocket, as in Fig. 5. Zero on the abscissa, therefore, represents a perfect fit of the film on the intermittent sprocket in question, and, as before, all points to the left of the line represent Case I, in which the pitch of the film is greater than that of the sprocket, and

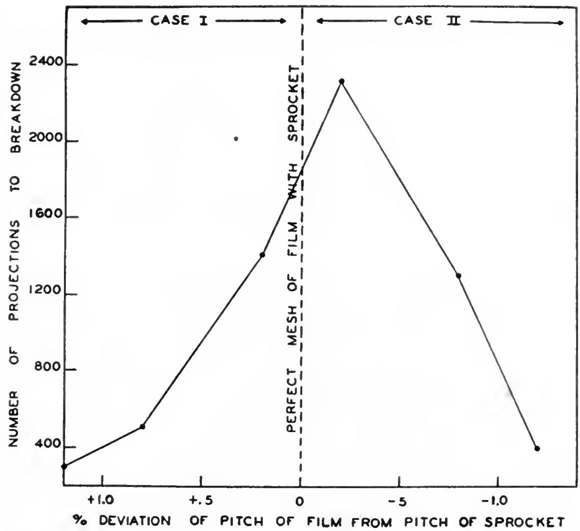


FIG. 5. Relationship between the per cent deviation of the film from the sprocket pitch and the number of projections that produce film breakdown.

all points to the right of this line represent Case II, in which the pitch of the film is less than that of the sprocket. Thus, films of any pitch whatsoever may be run on projectors with intermittent sprockets of different diameter and, if other factors are controlled, the results will still be comparable. For example, the data presented by D. R. White[2] at the 1943 Spring Meeting, in which films of nearly standard pitch were run on a Series of Different diameter intermittent sprockets, can be presented graphically in this manner and compared with the results just given.

These principles have been recognized by film manufacturers and projector manufacturers alike. The approval of the 0.945-in. diameter intermittent sprocket and its adoption in 1930 as an American Standard came as a result of this general agreement. Why, then, has the 0.945-in. sprocket not been in general use in this country?*

The answer is that the projector manufacturers have been concerned over the possibility of increased wear of the sprockets, their fears being based on the theory then held. It is quite obvious that if we consider the film as a steel tape (Fig. 1), the wedging action of

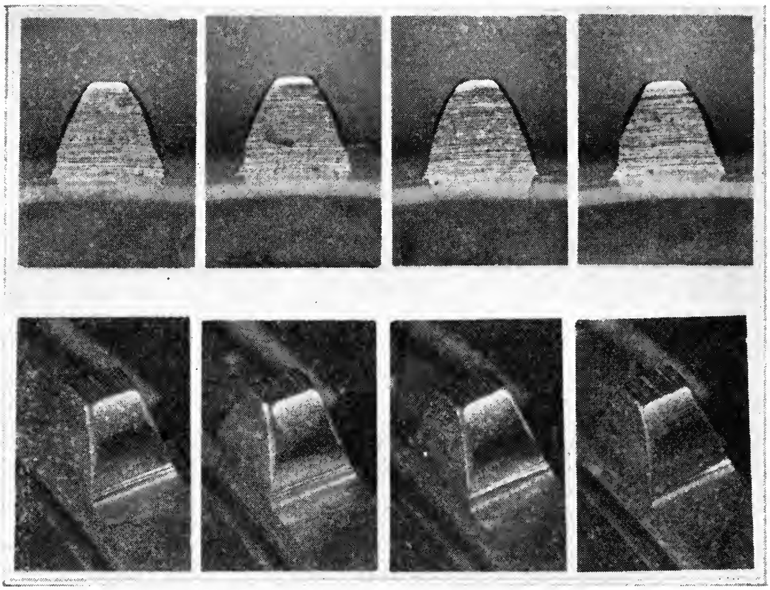


FIG. 6. Wear on 0.943-in. sprocket after 20 months' use in Riviera Theatre, Rochester, New York.

the film onto the entering tooth should wear away the face of the tooth uniformly. When, however, the pitches of the film and the sprocket are equal, or the pitch of the film is less than that of the

* As early as 1933, larger-diameter intermittent sprockets were in use in several European projectors. In 1933, intermittent sprockets used on Ernemann projectors in France and Germany measured 0.9452 in. in diameter, and those on the Kalle projectors in England, 0.941 in. in diameter. The Phillips projector, which was described before the Society by T. W. M. Schaffers,[3] is equipped with 0.945-in. diameter intermittent sprockets. When conditions permit, a survey of the results obtained from the use of these larger-diameter sprockets in Europe should be of value.

sprocket, as in Fig. 2, the entire wear should occur at the point of contact—or at the base of the tooth. The wearing away of the base of the tooth should give it a hooked shape which would result in rapid film wear.

The principal objective of the theater tests, as outlined by the Subcommittee on Projector Sprocket Design, was the determination of the comparative wear of the 0.935-in. and the oversized intermittent

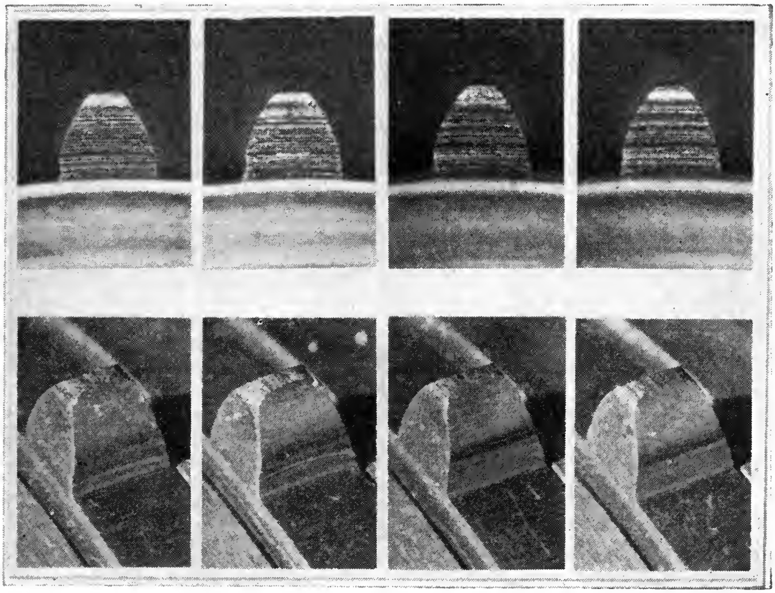


FIG. 7. Wear on 0.935-in. sprocket after 20 months' use in Riviera Theatre, Rochester, New York.

sprockets. Fortunately, our former theory in regard to sprocket wear was somewhat in error. In every theater in which these oversized sprockets have been compared with the 0.935-in. ones, the latter have shown the more wear. In Figs. 6 and 7 are shown the various degrees of wear on each of 4 teeth from a set of sprockets removed after 20 months' operation in the Riviera Theatre in Rochester, N. Y. Fig. 6 shows the wear on the 0.943-in. sprocket. The wear on this larger-diameter sprocket is predominantly at the base, as the theory suggested, but it is slight and not sharply defined. There is no evidence of a hook. The wear on the corresponding 0.935-in. sprocket is shown in Fig. 7. Note that in the case of this sprocket, the film has cut deep grooves into the face of the teeth. The striking thing about these grooves is that they vary in depth and in the distance from the base of each of the 4 teeth.

A similar comparison is given in Fig. 8 which shows the various degrees of wear on each of 4 teeth of a set of 3 sprockets removed from the RKO 58th Street Theatre, New York City, after 1552 hrs projec-

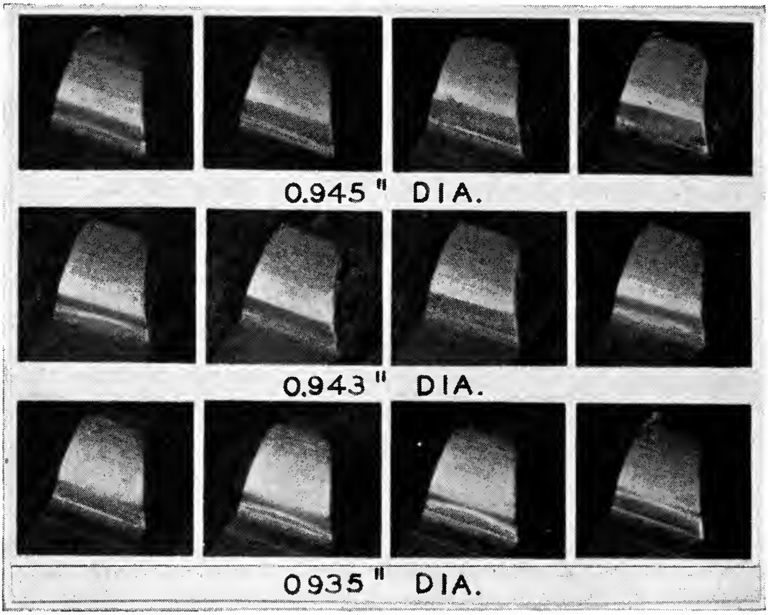


FIG. 8. Comparative wear on 3 sprockets used in RKO 58th Street Theatre, New York, for 1552 hr.

tion time for each sprocket. Again, the wear on the 0.935-in. sprocket is greater than that on the oversized sprockets. This difference in type and extent of wear is more apparent when the sprocket teeth are examined with the aid of a binocular microscope than in the photomicrograph. Obviously, the analogy of the sprocket and the steel tape to the case of the sprocket and the film is not complete. It is hoped that in the near future there will be more concrete evidence of the nature of the action of film on intermittent sprockets during the pull-down cycle.

The foregoing remarks relate to the difference in the nature of the wear on the sprocket teeth. The increased extent of wear on the 0.935-in. intermittent sprocket as compared to that on the oversized sprocket is explainable. In the case of the former, the additional force necessary to thrust the film ahead of the rotational speed of the sprocket manifests itself in increased wear of both film and sprocket teeth. When the pitches of film and sprocket are equal, the driving force is spread over 2, or even 3 teeth simultaneously—resulting in decreased wear on both film and sprocket. This condition should hold true even when the 2 pitches are nearly equal, as a result of the local stretching of the film upon impact.

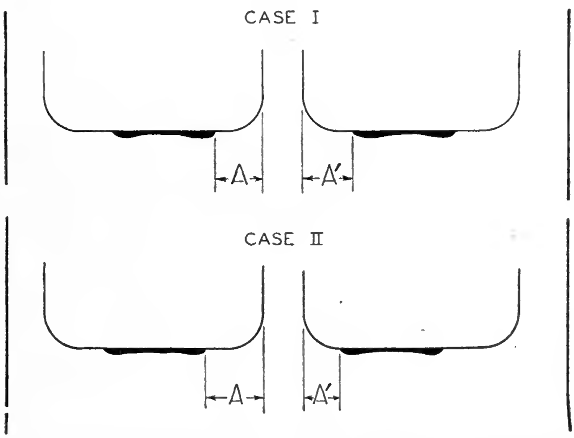


FIG. 9. Impact marks of an intermittent-sprocket tooth on a film perforation. Case I—Correct Alignment; Case II—Incorrect Alignment.

It is therefore gratifying that by the use of increased diameter intermittent sprockets substantially increased film life can be achieved with no increase in sprocket wear.

Relationship Between the Alignment of the Film on the Intermittent Sprocket and Film Wear.—Fig. 9 is a drawing of the marks made on the standard positive-type perforation by the intermittent sprocket on one passage through a projector. It is impossible to align the film on the intermittent sprocket so that the latter will strike the film in the center of each row of perforations. This is because the transverse pitch of the sprocket is less than that of the film. If the film is centered on the intermittent sprocket on one row of perforations, the sprocket will ride very near the inside corner of the other row of perforations, as in Case II, and wear or rupture will then almost invariably occur at the point nearest the sprocket tooth, or at A'. It is believed that the best alignment with the present intermittent sprocket occurs when the sprocket is centered as nearly as possible on each row of perforations, or so that distances A and A' are equal, as in Case I. Even under this condition, the preponderance of wear occurs in the corners at A and A' and occasionally at the outer corners also. Only rarely does it occur directly under the point of impact, in the case of the 0.935-in. intermittent. This is because the perforation is weakest at the points of curvature, the

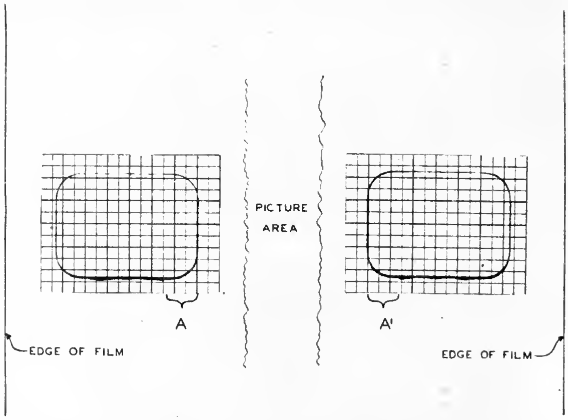


FIG. 10. Correct alignment of film with standard positive-type perforations on an intermittent sprocket (actual photograph).

wedging-on action causes a strain throughout this entire area, and rupture occurs at the weakest point.

Correct alignment of the film on the intermittent sprocket in the case of the standard positive-type perforations is illustrated in Fig. 10.* Note that the distance from the inside edge of the left-hand

* The film was allowed to make one passage through the projector, thereby leaving the mark of the intermittent on the perforation. The film was then placed in a Recordak Viewer, a projection made of the marked perforations onto graph paper, and the superimposed image of the perforation on the graph paper photographed. In practice, millimeter paper is used for more precise alignment. In these photographs, 1/2-cm grids were used to facilitate reproduction.

perforation to the point of impact of the intermittent-sprocket tooth is nearly 3 divisions of the grid, and that the corresponding distance on the opposite row of perforations is again nearly 3 divisions. In other words, distances A and A' are equal. Perfect alignment can rarely be obtained by predetermination from measurements made on the projector, *i. e.*, by mechanical setup. It can best be accomplished by allowing the intermittent sprocket to mark the perforations, and then, by projection of these markings on graph paper, making the necessary adjustment in alignment.

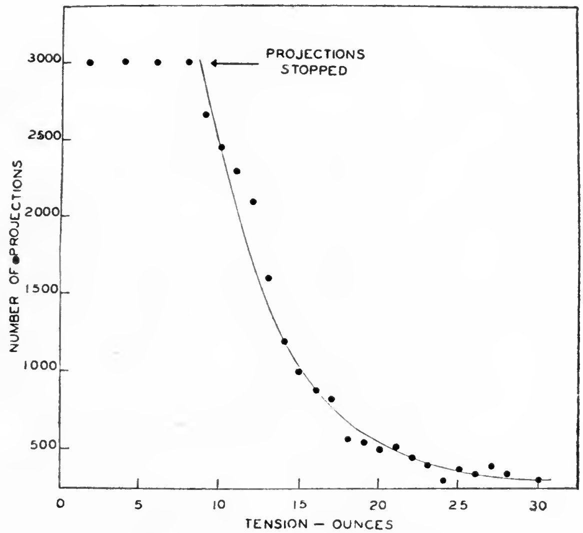


FIG. 11. Relation between the tension in the gate and the number of projections that produce film breakdown.

Although there are no data on the subject available at this time, experiments have indicated that double the number of projections could be obtained from films which are exactly centered on the intermittent sprocket compared with those which are only slightly misaligned.

Relation Between the Tension on the Film in the Projector Gate and Film Wear.—The relation between the tension of the film in the gate and the number of projections necessary to produce complete breakdown is shown in Fig. 11. It will be noted that on this particular machine the number of passages vary from about 300 at a tension of 30 oz* to 3000 at a tension of 8 oz. At tensions lower than 8 oz, the samples were not run to breakdown, but were removed after 3000 passages and examined for wear.

On the projector on which these tests were run we could see no difference in steadiness of the screen image with tensions greater than about 4 oz, but below this point there was definite unsteadiness.

A survey of a number of theater projectors in our district showed gate tensions ranging from about 20 oz to about 10 oz. From the curve we see that these 2 extremes in tension would produce a fivefold change in the wear life of film.

This relationship between the number of projections and the gate tension represents but one series of tests on one type of projector. On this projector, the gate tension may be changed by means of a thumbscrew which alters the loading of the central coil springs which, in turn, controls the pressure on the center tension pads.

There is some evidence to indicate that whereas the over-all effect of tension on most projectors may be the same as that just given, it is much more difficult to determine. For instance, in many of the older types of projectors the gate tension is controlled by individual cantilever springs, the adjustment of which can be made only by hand manipulation, *i. e.*, by bending the springs. Moreover, on many types of projectors in which the film is not positively edge-guided through the gate, a change in gate tension produces a change in alignment which in itself alters the result.

The answer, then, to the question "How many times can film be run through a projector?" appears to be "It will run as many times as we wish to make it run." If the pitch of the present intermittent sprocket is altered so as to avoid the tearing action of the sprocket teeth against the film perforations, and if the questions of alignment and tension can be solved in cooperation with the projectionist, it is believed that most films are capable of delivering many times the number of projections they will ever be called upon to make.

---

* The tension in the gate can be measured easily by inserting a short strip of film in the gate and withdrawing it upward through the gate by the steady pull of a hand scale, or if preferred, by other mechanical means, so that the force required to move the strip in the gate can be measured. On a theater projector, the upper magazine must be removed to facilitate withdrawing of the test strip, or a special jig must be used which allows the tension to be measured with the magazine in place.

EDGE DAMAGE

All too frequently a print is received by the exchange directly from a theater with torn edges, or in some instances with one row of perforations entirely missing from some sections. How can this be? In some cases the print has been so badly damaged that projection in this condition would have been impossible. Yet the theater had made no complaint nor had they asked for another print. We must assume, therefore, that the print operated satisfactorily. Likewise, the reverse is true. Prints have been received by the theater directly from the exchange with the edges broken to the extent that several sections (2 to 3 ft in length) had to be removed before the roll could be projected again, and yet this print had been inspected carefully at the exchange and the inspector's seal affixed thereto. There is a preponderance of evidence to the effect that most of the damage occurred between the theater and the exchange.

The writer is aware that a certain amount of edge damage is caused by the film coming into contact with the sharp surfaces of defective reels—a condition brought about largely by the scarcity of new metal reels at this time. He is also aware that in certain rare cases, which each one of us can recall, the edges of the print have been damaged as a result of what we may call an accident, *i. e.*, the reel of film may have been dropped, the metal shipping case may have been dented or crushed, or the film may have jumped a sprocket at a splice. But let us not, in recalling some of these instances, assume that the major amount of edge damage comes from these causes. It is far too prevalent.

There is another observation which is very pertinent to this matter of edge damage, *i. e.*, the damage is confined largely to prints which have been in use long enough to become oily. It is very difficult to wind a smooth firm roll on a hand rewind when reels, which are wider than the film—and often misshapen—are used. Uneven winding leaves the edges of certain convolutions protruding farther than those immediately adjacent. If the roll is not wound too tightly, and if the film is not oily, these protruding edges will slip back into place by pressure from the reel flanges. If the film is oily, however, a firm bond is formed between successive layers within the roll so that the protruding edges of an unevenly wound roll cannot slip back into place. When pressure is brought against these edges by the reel flanges during shipment, or even by careless handling, they will be damaged and, in some cases, even broken off completely, as shown

FIG. 12. An example of edge damage on positive motion picture film.

in Fig. 12. Basically, the solution of this problem would be to ensure that all rolls are evenly wound and that no oil is allowed to get on the film. This would not be very practical, for both of these conditions will probably prevail for some time to come.

This problem of edge damage can be attacked from 2 angles:

(*1*) By providing protection for those edges of film which protrude;

(*2*) By surface-treating the film in such a manner that the protruding edges of film, *even when oily*, will telescope back into the roll without damage.

The first of these 2 methods, protection of the protruding edges, was discussed in a paper read at a recent meeting of the Society.[4] This proposed solution concerns the use of a white plastic band to replace the paper wrapper on exchange reels. The band which was described was approximately 0.040 in. thick and $^3/_{16}$ in. wider than the film. The greater width of the band, together with its stiffness, prevents to a large degree the bending over of the protruding edges of the film by the reel flanges.

A test was made to demonstrate the effectiveness of this type of band for the prevention of edge damage. Three 2000-ft rolls of processed positive motion picture film were spotted with oil throughout their entire length. Each roll was then projected 10 times in order to "bake" the oil into the film. The rolls were then mounted on 3 identical exchange reels, using a constant-tension winding mechanism. In the mounting of these rolls the film was forced first against one flange and then against the opposite flange in order to produce protruding edges. Around one roll was placed the conventional paper wrapper or band. Around another roll was placed the white plastic band. Around the third roll was placed a similar stiff band which instead of being plastic, was made of black pressboard. These reels of film were then placed in a 3-reel shipping case and given a handling test to simulate the abuse many cases of film undergo in shipment. The positions of the reels in the case were changed from time to time.

At the end of the test, the bands were removed and the reel flanges bent back so that the extent of edge damage could be seen. The result of the test is shown in Fig. 13. It can be seen that there is

FIG. 13. Comparative edge condition of film protected by stiff bands (not shown in picture) with edge condition of film wrapped with customary paper band.

some edge damage on the 2 rolls protected by the stiff bands, probably as a result of the severity of the treatment, but the edge damage on the roll covered by the paper wrapper is considerably greater. It is believed that by this simple expedient a large percentage of the edge damage to prints can be prevented.

The second method of attack, surface treatment, has been the subject of numerous investigations,[5] over a period of many years, often leading to patented processes. The principal objection to most of the existing processes lies in their inability to satisfy all the requirements of the ideal surface treatment at the same time. It is believed that an ideal surface treatment should accomplish the following:

(1) Provide a smooth coating of high gloss which will minimize the mottle on the screen from oil spots on the film.

(2) Give projection runs equal to or surpassing film having a liberal application of paraffin wax along the perforated area.

(3) Minimize or eliminate the edge damage previously mentioned by providing a slippery surface even when the print is oily. The rating of films for their ability to telescope when oily will be referred to hereafter as their "oily slip."

(4) Provide protection from surface abrasion.

TABLE 1

Waxes

Natural

Beeswax	Ozokerite
Ceresin	Paraffin

Vegetable

Candelilla	Japan	Palm
Carnauba	Curicury	

Synthetic and Trade Name

Albacer 1163	Dioctadecyl carbonate	Pentaerythritol diacetal
Albasol BB	Gelowax	Pentaerythritol di-N-butyral
Aminostearin	Glyceryl stearate	Pentaerythritol di stearate
Ammonium stearate	Glyco dilaurate	Pentaerythritol mono stearate
Amorwax 1200 A	Glycoride	Pentaerythritol tetra stearate
Aryl	Glycowax B 430	Pentachlorcumene
BZ-A	Glycowax A 1639	Propylene stearate
Barnsdall special	Halowax	Rezowax A
Betanol 107	Hurco	Rezowax B
Betanol 114	I.G. Wax E	Santowax M
Betanol 152	I.G. Wax O. P.	Santowax MH
Cantol	Johnson's WM 119	Santowax O
Carbowaxes	Johnson's WM 169C	Santowax P
Carnube	Lauric ethanolamide	Santowax R
Cereflux	Old English Impervium	Span 40
Cetyl alcohol	Opal	Synthowax
Diglyco stearate	Pentawax 217	Witco Hamp No. 70

Since it is believed that no commercially available surface treatment satisfies all these requirements, a study is now being made of the problem. The data to be presented and the conclusions to be drawn are in the nature of a progress report. The scope of the problem and its complexity preclude a final answer at this time.

A large number of waxes were examined, as shown in Table 1, for their solubility characteristics and their general appearance when applied to the surfaces of film in any reasonable concentration. Various concentrations of these waxes in carbon tetrachloride were applied to the entire emulsion surface of positive films by the plush-wick method on a machine designed for this purpose.

From the preliminary survey of this large number of samples only the waxes shown in Table 2 were considered worthy of further testing.

TABLE 2

Waxes judged most suitable for surface lubrication of motion picture positive film. For purposes of comparison, the samples were given an alphabetical rating for oily slip and scratch resistance—"A" representing the ideal.

Wax	Max. Useful Per Cent Conc. in CCl_4	Wear Life as Per Cent of Edge-Wax Check	Oily Slip	Scratch Resistance
Aristowax	0.06	73	D	C
Cantol	0.125	71	E	C
Pentawax 217	0.125	80	E	D
Glyco dilaurate	0.25	41	E	B
Johnson's WM 169C	0.125	59	B	B
Gelowax	0.06	46	E	C
Glycoride	0.06	46	E	C
Pentaerythritol tetra stearate	0.06	56	E	C
Candelilla	0.09	50	E	B
Santowax R	0.09	41	C	C
Ceresin	0.125	70	E	C
Ozokerite	0.125	88	C−	C
Synthowax	0.20	123	D	C
Betanol 107	0.25	61	C+	B
Betanol 114	0.125	95	C−	B+
Betanol 152	...	56	C−	C
Carnube	0.125	45	D	B
Pentaerythritol diacetal	0.25	44	C−	D
Pentaerythritol di-N-butyral	0.25	51	C+	D
Dioctadecyl carbonate	0.125	55	D	B
Johnson's WM 169C (Repeat Test)	0.125	80	B	B
Johnson's WM (Both Sides)	0.125	129	B	B
Eastman Edge Wax (Perforated Area Only)	3.5	100	D	D

One thousand-ft rolls of film were coated with each wax from the concentrations in carbon tetrachloride indicated, and examined for appearance, wearing quality, oily slip, and scratch resistance. Note how low the concentrations of wax must be to give a surface coating of good appearance. Most wax applications in these low concentrations give only approximately one-half the wear life of edge-waxed film. In the oily-slip test, at least 900 ft of each sample roll was liberally spotted with machine oil throughout its entire length and then projected 10 times on a representative theater projector to bake the oil into the film. Apparently, many waxes, together with oil, yield a greaselike composition which causes the layers of film to adhere together, since in many cases the lubricated films have a lower rating on the oily-slip test than untreated films.

Of the waxes examined thus far, only one seemed to be outstanding in respect to the telescoping of an oily roll—Johnson's Industrial Wax *WM-169-B*. For some reason, the waxes used in this mixture give a smooth, glossy coating which imparts a slip to the film layers even when the film is oily. In the first test, the wearing property was not satisfactory. In a repeat test, it was much better, and when applied to both sides of the film, it was better than that of the edge-waxed sample. It is admitted that the application of wax to both sides of film may present other problems—such as difficulty in splicing, *etc.*

SCRATCH RESISTANCE AND SCRATCH PROTECTION

Any simple wax application depends for its effectiveness on the principle that the treated surfaces will be more resistant to abrasion than those not similarly treated. Whereas this is true in some cases, as seen in Table 2, the fact remains that no practical film surface has been found which will resist abrasion indefinitely. Therefore, when these treated surfaces become abraded, they present the same problem as do any other scratched films.

We may distinguish, then, between the resistance offered to abrasion by a simple lubricant and the protection of the film surfaces from abrasion by a thicker coating, such as a lacquer. In addition, it is necessary not only to have the lacquer coating of such a thickness that it will carry the abrasion which normally is borne by the film surfaces, but, to be really effective, it must be removable and renewable. Thus, at any time in the life of the film, the entire external surfaces of the film can be renewed. Only in this way can "new print" quality be maintained.

At a meeting of the SMPE in Hollywood in 1940, a method for the scratch protection of motion picture film which fulfilled these requirements was presented.[6] The novelty of the method lay not in the fact that it was a smooth, glossy protective coating for either or both surfaces of nitrate and safety films, but in the fact that the protective coating was removable in dilute alkali (or developer) and thus could be replaced from time to time, if necessary. The fact that new print quality, in regard to oil mottle and all normal abrasion, could be maintained throughout the life of a print was demonstrated at that time. A print was placed at our disposal by J. M. Nickolaus of Metro-Goldwyn-Mayer Studios. After treatment, the print was put into service through the Buffalo exchange of MGM. A portion of the print was shown here after 35 bookings or an estimated 164 runs. The conclusions reached at that time were that:

(*1*) The lacquered section was noticeably more free from oil mottle and scratches than the unlacquered section;

(*2*) The section which had its original lacquer removed and replaced by a fresh coating prior to its showing here was judged to have "new print" quality.

The Ace Laboratory, Brooklyn, has used the lacquer for several years on their negatives as an insurance against abrasion. The Ace Laboratory has also used the lacquer on both surfaces of their color film, mainly for the prevention of color distortions arising from the effect of oil on the surface of the film.

The process has never been used extensively for positive film. This may be because in the past it was easier to replace the occasional severely scratched print than to insure every print against abrasion.

Furthermore, since the beginning of the war, the materials used in this lacquer have been on high priority. On account of the existing print shortage, every effort is now being made to make the lacquer available, even for use on prints.

If the original lacquer, as announced in 1940, is compared with the simple waxes, it would be rated as follows:

(*a*) Good in appearance and oil-mottle prevention.
(*b*) Unsatisfactory for wearing property without additional lubrication.
(*c*) Poor for oily slip.
(*d*) Fair to poor for scratch resistance.
(*e*) Very good for scratch protection.

Recently all of the available waxes were tried separately and, in some cases, in combinations, as an integral part of the lacquer. Several combinations were found to be an improvement over either the wax alone or the lacquer alone. One combination was found to be exceptionally good for scratch resistance, good for oily slip, but not satisfactory for wearing quality. If, however, the print is edge-waxed in addition to the lacquer-wax coating, the treatment seems to satisfy all the requirements previously given for an ideal surface treatment.

The work will be continued. Perhaps something more simple and effective will be discovered. Extensive trade tests will have to be made on the most promising developments.

CONCLUSIONS

It has been shown that an increase in the wear life of film will result if the diameter of the intermittent sprocket is increased from 0.935 in. to 0.943 in. This fact has been demonstrated many times by laboratory tests. The results in the laboratory have been verified by trade tests in which it has been shown that the 0.943-in. intermittent sprocket will give from 2 to 3 times the number of projections, before breakdown of the film, as the 0.935-in. sprocket after each sprocket had been in theater use for over 1500 hr.

Laboratory tests indicate that a decrease in gate tension would increase the wear life of film severalfold.

The centering of the perforations on the intermittent sprocket has a considerable bearing on the wear life of film.

Mention has been made of the necessity for the reduction of the damage to the edges of prints. Two methods by which this damage can be minimized have been described.

Abrasion of the surface of film can be reduced by the application of wax to the entire surface. Surface abrasion can be eliminated almost completely by the application of a renewable lacquer.

ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation to Dr. E. K. Carver for his many helpful suggestions and for continued guidance in the preparation of the paper, and to the various members of the film-testing departments of the Eastman Kodak Company for their contributions.

REFERENCES

[1] JONES, J. G.: "Film Sprocket Design," *Trans. Soc. Mot. Pict. Eng.*, 17 (Oct. 1923), p. 55.

[2] WHITE, D. R., AND DEMOOS, C.: "A Note on the Projection Life of Film," *J. Soc. Mot. Pict. Eng.*, **41**, 4 (Oct., 1943), p. 297.

[3] SCHAFFERS, T. W. M.: "A New 35-Mm Projector with a New Light Source," *J. Soc. Mot. Pict. Eng.*, **44**, 3 (Mar., 1945), p. 203.

[4] KULKA, T.: "A Greatly Improved Reel Band," presented Oct. 16, 1944, at the SMPE Technical Conference in New York.

[5] CRABTREE, J. I., SANDVIK, O., AND IVES, C. E.: "The Surface Treatment of Sound Film," *J. Soc. Mot. Pict. Eng.*, **14**, 3 (Mar., 1930) p. 275; also CRABTREE,

J. I., AND IVES, C. E., "The Lubrication of Motion Picture Film," *Internat. Projectionist*, **3** (July, 1932), p. 7.

[6] TALBOT, R. H.: "A New Treatment for the Prevention of Film Abrasion and Oil Mottle," *J. Soc. Mot. Pict. Eng.*, **36,** 2 (Feb., 1941), p. 191.

DISCUSSION

MR. HERBERT GRIFFIN: The paper is now open for discussion.

MR. M. S. LESHING: A few years ago the Eastman people advocated a protective lacquer treatment of negative film right after processing. After a period of time the question of the lacquer died. What happened to it?

MR. TALBOT to MR. D. E. HYNDMAN: Don, would you like to answer that question?

MR. HYNDMAN: To my knowledge the Eastman Kodak Company, as a policy, did advocate applying a protective lacquer to either processed positive or negative film, but the use of it was never discouraged.

MR. LESHING: The reason, I think, that the Kodak Company planned using a lacquer is shown by the fact that Mr. Capstaff was, as he told us, providing the developing machine in the Kodak Research Laboratories with a special cabinet for applying the lacquer to the negatives.

MR. HYNDMAN: The only answer I can give would be my personal opinion. The Eastman Kodak Company has sold and delivered lacquer to anyone desiring it. It was and is still used mainly by the Ace Film Laboratories in Brooklyn. New York. It has used lacquer for a period of years. I have inspected, personally, negatives on which lacquer has been applied. After 475 release prints have been struck from the negative, the lacquer was removed. The concensus of opinion was that the negative looked practically as good as before printing. For this reason Ace Film Laboratories, Inc., continued to use the lacquer. We would sell the lacquer to anyone who wishes it, but we have not tried to thrust its use on any concern. It is available.

MR. TALBOT: As a service of the Kodak Company we will provide specific recommendations on equipment to apply the lacquer.

MR. GRIFFIN: Any more discussion, please?

MR. PAUL ALLEN: It seems to me that the industry is missing an opportunity. If it would purchase 30,000 sprockets at about $150,000, it would save about half of the film cost. There are the facts that should be presented.

MR. GRIFFIN: As a representative of the company mentioned, the International Projector Corp., probably one of the largest manufacturers of sprockets in the world, I have been most interested in this subject for many, many years and am heartily in accord with what this paper has shown. As a matter of fact I presented the same type of paper in the past which I read before the Society in 1933 and which was published in the January 1934 issue of our JOURNAL. However, on the basis of that I issued a preemptory order to our Engineering Department to change all intermittent sprockets from 0.935 in. to 0.945 in. diameter which we promptly did and probably shipped several thousands. Shortly thereafter we were called upon to replace sprockets for the reason that there was a noise regardless of what the previous speaker said. A noise would show up from a slight undercut of the pull-down tooth. We replaced all of the 0.945 sprockets. I agree that in those days the shrinkage problem was more acute than it is today.

However, that situation did exist with the result that we were called upon to replace thousands of sprockets. Our company is in business to make money and cannot continue to replace sprockets. The projectionists just would not use them. I agree with the gentleman who said it would be a wise plan on the part of the film manufacturers to supply the sprockets themselves, but I don't think that would work either, as they would have the same problem and the same results. Anybody like to rebut that?

MR. TALBOT: May I ask you one question? Are you sure that those sprockets used at that time were hardened steel or were they soft steel?

MR. GRIFFIN: They were hardened and ground steel. The radii were ground also on all of the teeth and still are.

MR. TALBOT: The only thing that I can say, more or less in rebuttal, would be that if these sprockets have been in use for approximately one year and still give double the life of film, it would pay the exchanges to replace the sprockets today if they had to. I mean, if after a year they are still getting better runs, even if it were true at the end of a year the sprockets began to wear and had to be replaced, it would still seem worth while for the exchanges to do this rather than have to buy so much film.

MR. GRIFFIN: With that I heartily agree. Nevertheless we had to shoulder the burden and would not want to have to do it again. I still want to recommend a 0.943-in. sprocket.

Any further discussion?

MR. E. J. DENISON: Regarding edge damage to film, mentioned in Mr. Talbot's paper, it has been my experience over a period of years covering film exchanges that a great deal of the edge damage is actually done during rewinding of the film in the exchanges and not by projectionists or projection machines. If one will visit the average film exchange today he will find that rewinds are badly out of alignment, with the result that the film traveling from the free-running reel to the rewinding reel is drawn across the side of the rewinding reel, resulting in the film being broken through from the outer edge to the perforations. Further, the out-of-line setup of the rewinds results in some convolutions of the film protruding from the side of the roll. When one reel is stacked on top of another during handling by the film shipper or truck driver, these convolutions which protrude from the roll are broken down by weight, resulting, of course, in considerable edge damage to the film.

The matter of edge damage to film has been discussed before the National Film Carriers Association for several years past, with demonstrations as to the cause of this particular type of damage, as well as the SMPE, without result. The National Film Carriers Association has taken serious steps in the past to prevent undue rough handling by their drivers, but to my knowledge they have had little success.

From time to time the idea has been advanced that some of this edge damage is due to poor quality of film which, of course, is not true. A number of years ago I made a slow-motion picture for Paramount showing damage to film due to improper splicing. This picture demonstrated the necessity of proper splicing in order to prevent damage to the film at the point of splicing. Today several of the distributors have their exchanges equipped with a modern and efficient splicing device, with the result that these distributors have very little film damaged due to splicing. Before making the picture demonstrating results of bad splicing, I gathered film scraps from some 35 exchanges throughout the United States, and analyzed and catalogued each particular type of damage due to improper splicing. The result of this analysis was the slow-motion film mentioned.

The point I am trying to make is this: I believe that in order to overcome excessive edge damage to film, or any other type of damage, it is necessary to visit a sufficient number of exchanges throughout the country, gather samples of film damage, analyze and catalogue them. Any particular type of damage to film can quickly be catalogued by an expert and only then can proper steps be taken to correct this evil. In my opinion, testing or analyzing film damage cannot be satisfactorily arrived at in a laboratory. The life of motion picture film has been greatly increased in the past years due to intelligent investigation and analysis of causes. There is still considerable research to be done to bring about the maximum life of positive prints and most of these causes will be found in the field, mainly in the film exchanges.

With the advent of sound it was necessary to keep projector heads in a much better mechanical condition than in the silent days. There have been many attempts to correct sprocket pitch, take-up tension, use of bad reels, *etc.*, all of which are contributing factors to various types of film damage.

Positive film is handled only in exchanges and theaters, consequently it is my belief that a thorough survey of these 2 branches of the industry should result in the establishment of the necessary standards for the proper handling of film.

First, the investigation should be made in the exchanges where, it will be found, a great deal of the damage to film occurs. There should be designed a good rewind and a blueprint for the installation of these rewinds. Also it is considered practical to install between the rewinds a guide for keeping the convolutions of the roll of film smooth in its travel from the free-running reel to the rewinding reel. Good reels should always be used in connection with the inspection and rewinding of film in exchanges. All devices used in the exchange in connection with inspection and handling of film should be engineered into the general setup.

In the past there has been a number of treatments for positive film tested. Some were found beneficial, others showed no improvement in the life of the film. Today it is definitely known that there are certain treatments for positive film that actually retards scratching, keeps the film pliable, retards oil absorption, and, in general, while not necessarily prolonging the life of the film by such a treatment, will keep the film in a new condition for a longer period of time.

It is this speaker's thought that it would not be amiss to appoint a committee of experts to make a thorough survey on the care and handling of film.

MR. GRIFFIN: I hope the Editorial Board will find it possible to promptly publish this paper. It will be most interesting to all projection manufacturers including my own company. Thank you, Mr. Talbot.

STUDY OF RADIANT ENERGY AT MOTION PICTURE FILM APERTURE*

R. J. ZAVESKY, M. R. NULL, AND W. W. LOZIER**

Summary.—*The results of a study of the quantity and quality of radiant energy incident at the center of the film aperture with various carbon arc motion picture projection systems are reported. The effect on the spectral quality and quantity of the radiant energy of various filters used primarily to remove nonvisible energy is also discussed.*

In motion picture projection, radiant energy from a light source is concentrated on the film at the projector aperture and transmitted by the projection lens to form the picture image on the projection screen. Previous publications in the JOURNAL have given pertinent data concerning the carbon arcs and lamps and optical systems commonly employed for this purpose. The useful portion of the total radiant energy of the projected beam is that of wavelengths visible to the human eye. Information has been published relative to the spectral energy distribution throughout the visible wavelength region both for the light from the bare arcs[1] and for the light falling on the projection screen.[2] This visible radiation is accompanied by a certain amount of radiant energy of wavelengths outside the visible region, particularly in the infrared region. The heating effect of this energy is of interest and importance in connection with the development of improved arcs and optics to concentrate higher light intensities on the aperture. Attention has been focused on this heating effect by the recent work of Carver[3] and his associates wherein it has been shown that under some circumstances the intensity of the radiant energy at the aperture distorts the film and causes the picture to go "in and out of focus." This has emphasized the need for fundamental information on the intensity and spectral constitution of the radiant energy at the film aperture.

The following discussion deals with this subject and with some methods for removing radiant energy which does not contribute to seeing.

* Presented Oct. 16, 1944, at the Technical Conference in New York.

** National Carbon Company, Inc., Fostoria, Ohio.

Radiant Energy Intensity—Method of Measurement.—The measurement of the quality and quantity of radiant energy at the center of the film aperture was made with the system indicated in Fig. 1. Mirror systems as well as the condenser system sketched were studied. Prior to making the heat measurements with the arrangement shown, the regular optical system including aperture plate and projection lens was set up. The entire system was then adjusted to give the maximum light intensity at the center of the screen. This resulted in approximately 65 per cent as much light at the sides as at the center of the screen. After this adjustment was made, the film aperture was replaced by a plate having a pinhole slightly more than 2 mm in diameter and so positioned as to correspond to the center of the film aperture. The pinhole aper-

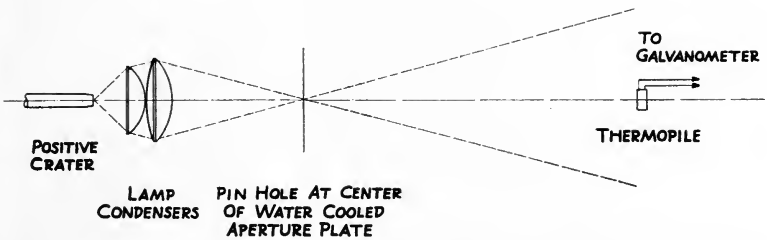


FIG. 1. Diagram of system for measuring radiant energy at the center of film aperture.

ture plate was placed directly in the beam with no shutters, screens, or filters between it and the light source. The plate containing the pinhole was water-cooled to prevent distortion or damage. The thermopile was placed at various positions in the beam, at a suitable distance from the pinhole, as shown on Fig. 1. The thermopile output was measured by a sensitive galvanometer. To obtain measurements in absolute units the thermopile-galvanometer combination was calibrated using a Bureau of Standards carbon filament radiation standard.

The thermopile with its fluorite window is sensitive to radiation of wavelengths from 1700 to 120,000 A. However, absorption by the glass of the condensers or mirrors in the optical system limits the beam radiation reaching the aperture to wavelengths of 3400 to 42,000 A. Through the use of quartz water cell and red glass filters, this total radiation may be broken down into the following parts:[4]

(1) 3400 to 6300 A
(2) 6300 to 11,250 A
(3) 11,250 to 42,000 A

The thermopile readings obtained in different positions over the beam were integrated to obtain both the total energy passing through the pinhole and the energy in the 3 wave bands given above. From these values and the area of the pinhole the reported values of watts per square millimeter were calculated.

Radiant Energy Intensity—Results.—A variety of popular carbon arc motion picture projection systems was studied. These are listed in Table 1 and ranged from a low-intensity arc at 32 amp to a super high-intensity arc at 170 amp. The energy measurements at the center of the aperture were made as just described. The results of these determinations are summarized in Table 1.

The sources and optical systems listed in Table 1 represent typical units used in motion picture projection and include low-intensity, copper-coated, nonrotated high-intensity and plain rotated high-intensity carbon arcs. The data on the total radiant energy intensity at the center of the film aperture show a range of 3 to 1, from 1.05 w per sq mm for the 13.6-mm source at 170 amp to 0.35 w per sq mm for the 12-mm source at 32 amp. This signifies that there is potentially 3 times as much heating effect on the center of the film at the aperture for the system with 13.6-mm carbons at 170 amp than for the system with 12-mm carbons at 32 amp. The measurements in Table 1 also show the portion of the total energy in the regions (*1*) below 6300 A (approx. 3400 to 6300 A), (*2*) 6300 to 11,250 A, and (3) 11,250 to 42,000 A. Considering the system with 13.6-mm carbons at 170 amp, for instance, 41 per cent of the total radiant energy is of wavelengths shorter than 6300 A and 59 per cent is of wavelengths longer than this value.

All of the radiant energy absorbed by the film contributes to heating, but only the visible energy transmitted by the film is effective for seeing. Since the filter combinations conveniently available do not precisely isolate the visible region 4000–7000 A, the per cent of the total energy of wavelengths within these limits was calculated from previous spectral energy distribution data[2] and from the measurements of energy in the 3400–6300-A band shown in Table 1. The radiant energy incident at the center of the film aperture for the projection systems listed in Table 1 is composed of approximately 50 per cent visible energy for the high-intensity sources and 25 per cent visible

TABLE 1

Radiant Energy Intensity at Center of Film Aperture

Item	Carbons		Arc		Lamp Optical Systems	*Total Energy Flux at Aperture Center Watts per sq mm	Measured Per Cent of Total Energy Flux in Indicated Spectral Regions			Calculated Per Cent of Total Energy
	Positive	Negative	Amps	Volts			Below 6300A	6300–11,250A	11,250–42,000A	4000–7000A
1	12-mm L.I. Proj.	8-mm L.I. Proj.	32	55	10 1/4-in. Dia. $f/2.3$ Mirror	0.35	20	37	43	24
2	7-mm "Suprex"	6-mm "Orotip" *C*	50	37	14-in. Dia. $f/2.3$ Mirror	0.55	39	33	28	48
3	8-mm "Suprex"	7-mm "Orotip" *C*	70	40	14-in. Dia. $f/2.3$ Mirror	0.65	44	31	25	52
4	13.6-mm H.I. Proj.	7/16-in. "Orotip"	125	68	Condensers at $f/2.0$	0.75	40	36	24	48
5	13.6-mm H.I. Proj.	1/2-in. "Orotip"	150	78	Condensers at $f/2.0$	0.95	40	38	22	...
6	13.6-mm S.H.I. Proj.	1/2-in. H.D. "Orotip"	170	75	Condensers at $f/2.0$	1.05	41	38	21	...

* No projector shutter or filters and carbon position and lamp optical system adjusted for approximately maximum center screen light.

energy for the low-intensity 12-mm source, with the remaining energy almost entirely within the infrared region. Therefore it can be seen that high-intensity carbon arc sources give approximately twice as much light per unit of heat as low-intensity arcs.

Filters for Removal of Infrared.—Since approximately 50 per cent of the radiant energy incident at the center of the film aperture with high-intensity carbon arc motion picture projection systems is nonvisible, it can be seen that the removal of this nonvisible energy before it reaches the aperture would reduce the potential heating effect with no loss in light. Practical means of approaching this ideal condition through the use of special filters forms the subject of this portion of the paper. Theoretically the removal of all radiant energy of wavelengths shorter than 4000 A and longer than 7000 A would give the best results in reducing heating effects without decreasing light. However, no filters practically available have cutoffs so precise, although they do furnish methods whereby a significant portion of the nonvisible energy may be removed.

Some liquid and some glass filters have been studied regarding their light and heat transmission properties, and regarding the amounts of energy they remove in the particular spectral regions listed in Table 1. These data are given in Table 2. A 2-in. thick layer of distilled water contained in a Pyrex cell removes about 15 per cent of the light and 40 per cent of the total energy from the beam of a high-intensity carbon arc motion picture projection system. A 3-mm thick sample of *395* Extra Light Shade Aklo or *2043X* Phosphate glass[5] removes 20 to 25 per cent of the light and 45 to 55 per cent of the total energy from such beams.

An important criterion of filter performance is its ability to remove as much nonvisible energy and to transmit as much visible energy as possible. The ratio of light and total energy transmission gives a relative measure of the amount of light per unit total radiant energy passed through the various filters. On the basis of 100 for the unfiltered beam, the amounts of light per unit total energy vary, as shown in Table 2, from 140 for the distilled water and the Aklo filters to 160 for the phosphate glass. This means that the quantity of light could be increased by 40 to 60 per cent without any increase in total energy, with sources having the quality of radiation of the 8-mm *Suprex* and 13.6-mm super high-intensity carbons listed in Table 2.

The water cell and the glass filters absorb a much greater proportion of invisible energy of wavelengths longer than 6300 A than they

TABLE 2

Transmission Characteristics of Various Filters with Carbon Arc Projection Systems

Item	Filter	Per Cent Transmission		Relative Amount of Light per Unit Total Radiant Energy Through Filters	Radiant Energy at Center of Film Aperture						
					Total	Below 6300 A		6300–11,250 A		11,250–42,000 A	
		*Visible 4000–7000 A	Total Energy		Watts per sq mm	Watts per sq mm	Per Cent	Watts per sq mm	Per Cent	Watts per sq mm	Per Cent
	8-mm "Suprex"–7-mm "Orotip" C at 70 Amp, 40 V with 14-in. Dia. f/2.3 Mirror										
1	None	100	100	100	0.65	0.29	(44)	0.20	(31)	0.16	(25)
2	2 in. Distilled Water in Pyrex Glass Cell	85	60	140	0.39	0.25	(64)	0.12	(32)	0.02	(4)
3	3-mm *395* Aklo	75	55	140	0.36	0.23	(63)	0.07	(21)	0.06	(16)
4	3-mm *2043X* Phosphate	80	50	160	0.32	0.25	(78)	0.06	(19)	0.01	(3)
	13.6-mm S.H.I.–1/2-in. H.D. "Orotip" at 170 Amp, 75 V with Condensers at f/2.0										
5	None	100	100	100	1.05	0.43	(41)	0.40	(38)	0.22	(21)
6	2 in. Distilled Water in Pyrex Glass Cell	85	60	140	0.63	0.37	(59)	0.24	(38)	0.02	(3)
7	3-mm *395* Aklo	75	55	140	0.58	0.35	(60)	0.14	(25)	0.09	(15)
8	3-mm *2043X* Phosphate	75	45	160	0.47	0.35	(75)	0.11	(22)	0.01	(3)

* Visible light transmissions were measured with Weston Photronic cell and Viscor filter.

do of shorter wavelengths. For example, the phosphate glass removes about four-fifths of the energy of wavelengths longer than 6300 A and only one-sixth of the portion of wavelengths shorter than this value. This results, for instance, in the case of a phosphate glass filter, in filtered beams having 75 per cent or more of the total energy of wavelengths shorter than 6300 A compared with 40 to 45 per cent of the total energy in this wavelength region for the unfiltered beam. The difference in quality and quantity of radiant energy between the unfiltered and filtered beams is given in Table 2 for each of the filters discussed. Of the filters listed, the water does not change the color temperature of the projected light, but the Aklo and Phosphate glass increase the color temperature slightly.

The use of filters which remove most of the radiant energy of wavelengths longer than 7000 A before the projected beam is concentrated at the film aperture can facilitate the utilization of improved carbon arc projection systems capable of producing more light on the screen.

REFERENCES

[1] BOWDITCH, F. T., AND DOWNES, A. C.: "Spectral Distributions and Color Temperatures of the Radiant Energy from Carbon Arcs Used in the Motion Picture Industry," *J. Soc. Mot. Pict. Eng.*, **XXX**, 4 (Apr., 1938), p. 400.

[2] NULL, M. R., LOZIER, W. W., AND JOY, D. B.: "The Color of Light on the Projection Screen," *J. Soc. Mot. Pict. Eng.*, **XXXVIII**, 3 (Mar., 1942), p. 219.

[3] 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**, 1 (July, 1943), p. 69.

[4] COBLENTZ, W. W., DORCAS, M. J., AND HUGHES, C. W.: "Radiometric Measurements on the Carbon Arc and Other Light Sources Used in Phototherapy," *Scient. Papers of the Bur. of Stand.*, **21**, 539 (Nov., 1926), p. 535.

[5] *395* Extra Light Shade Aklo supplied by Corning Glass Company; *2043X* Phosphate by Pittsburgh Plate Glass Co.

A 16-MM EDGE-NUMBERING MACHINE*

LLOYD THOMPSON**

Summary.—*A machine has been designed and built for edge-numbering 16-mm original and work prints. The numbers are printed with white ink so that they may be read easily on the black edges of reversal or color film. It is estimated that by using the machine the matching of originals with work prints can be done in about one-fourth the time formerly required. The service is available to anyone making pictures by the direct 16-mm method.*

Producers of direct 16-mm pictures have long recognized the value of a machine which could be used for edge-numbering original photography, work prints, sound tracks, or prints of sound tracks. There have been numerous proposals made that 16-mm film be edge-numbered with a latent image, but the film manufacturers have never gotten around to providing this except on special order.

Increased production of direct 16-mm photography and sound made the editing problem so acute that The Calvin Company decided to build an edge-numbering machine which could be used for edge-numbering original photography, work prints, and sound tracks after they had been developed. This system has been in use only a few months, but we have found that it has cut the time of matching originals to work prints by approximately 75 per cent, and that such work can now be done by relatively untrained persons.

The machine was made with a standard numbering head such as is used for edge-numbering 35-mm film. It is for this reason that the numbers which are printed along the edge of the film now are backward. We have on order a special numbering head with the numbers reversed so that the number will appear right-side up when printed along the edge of a black-and-white reversal or color film. However, this is not a serious problem as the person doing the editing soon learns to read the numbers almost as quickly as though they were right-side up, much the same as a printer reads type.

---

* Presented Oct. 17, 1944, at the Technical Conference in New York.

** The Calvin Company, Kansas City, Mo.

The numbers which are printed along the edge of the film are printed in white ink so that they can be easily read. When the standard purple or black numbering ink is used it has been found very difficult to read these numbers on black-and-white reversal film or on color film. A special ink was developed which prints legibly on the film and dries quickly so that there is no tendency to smear. Furthermore, if the numbers must be removed from the film they can be removed easily. However, they do not rub off during the normal editing process.

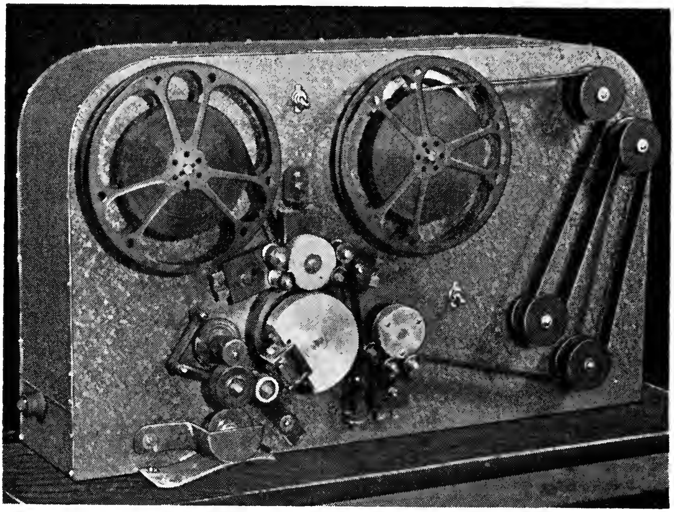


FIG. 1. A 16-mm edge-numbering machine for numbering developed film.

The numbers are accurately printed between the sprocket holes so that every number is legible and not blotted out by a perforation in the film. Furthermore, the machine has an accurate adjustment to compensate for shrinkage if the work print should be shorter or longer than the original. In other words, edge numbers can be printed by this method as accurately as though they were latent numbers on the original. If the latent image method is used in edge-numbering 16-mm film, it happens quite frequently that some numbers will fall in a sprocket hole and this sometimes makes them hard or impossible to follow.

It is assumed that producers of direct 16-mm photography will want to use work prints which have been made by the reversal method so as to give a positive picture image. Therefore the white ink is also

FIG. 2. Original 16-mm photography with edge numbering as it will appear when marked with the numbering head described in the text.

used for edge-numbering work prints. Sound tracks usually have clear edges, but the white ink can also be read on them.

There are some advantages to edge-numbering 16-mm film after it has been shot instead of using the latent image. In the first place, it is rather difficult to get film which is edge-numbered with a latent image and there is always a chance that a few rolls will be shot in a production which have not been edge-numbered. This, of course, is almost worse than no edge-numbering at all. In editing a 16-mm "show" it is customary to work in lengths of one reel or 360 to 390 ft. Therefore when the original photography is spliced together to make work prints it is spliced in lengths not longer than 390 ft. The reels are then printed. If we have a 1200-ft show, then we have 3 reels of original photography and 3 reels of work print before any cutting has been done. The work prints are synchronized with the original photography and the first reel of photography is numbered from one to 390 ft. The work print is then numbered with exactly the same numbers as were used on the original photography.

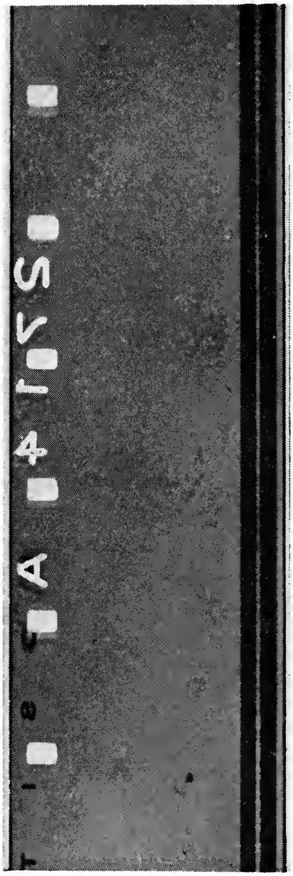


FIG. 3. A 16-mm sound track as it may appear if the recording is done on "A Winding" stock.

The second reel of original photography is then numbered from 400 to 790 ft, and the work print numbered the same way. The third reel is then numbered from 800 to 1190 ft, and the work print numbered in the same manner. The work print is then cut and after all the work has been done with the work print it is ready for the cutter to match the original photography with the work print.

In editing the picture, let us suppose that one of the scenes which was in the third reel was put in the first reel. By looking at the number on the work print the editor knows immediately that the scene was taken from the third reel of original photography because it carries the number *1052 ft.* With this information it is no trouble at all to locate the proper scene and put it in its proper place in the original photography.

SOME NOTES ON THE DUPLICATION OF 16-MM INTEGRAL TRIPACK COLOR FILMS*

WILLIAM H. OFFENHAUSER, JR.**

Summary.—*In the early days of Edison's work with motion pictures it seems that he, too, would indulge in that kind of daydreaming which begins "Wouldn't it be wonderful if —." There is ample evidence that the sentence ended with the words, "— we might have both color and sound in educational motion pictures." Edison's daydreaming is a reality today, if we choose to use the materials and processes already available.*

Kodachrome can be considered a successful process. Although its photographic speed is slower than black-and-white films, it is almost as convenient to use in the ordinary 16-mm camera. Like all color processes, it has its limitations which, if ignored, may lead to unnecessary disappointment. For most uses, these limitations can be avoided.

It must be recognized that there is no "perfect" color process. The usual requirements for a satisfactory color process include:

(*1*) *A suitable gray scale,*
(*2*) *Comparable color scales for the components,*
(*3*) *Accurate reproduction of color,*
(*4*) *Good differentiation of color.*

Unfortunately each of these requirements conflicts with at least one of the others. Ordinarily (*1*) *and* (*4*) *are favored over* (*3*); *the result of this compromise is satisfactory for most purposes.*

In medical work where accurate reproduction of color is often desired for diagnostic and similar purposes, some of the very common biological stains are not reproduced accurately in integral tripack color films. In such cases and in other specialized cases where the absorption spectra of the photographed material are "unfortunately" located, color accuracy must knowingly and intentionally be sacrificed for color differentiation.

Some data on films and filters not previously published are included. Much of this has been in use commercially for several years and has been helpful in solving in a practical way the everyday problems of color duplicating that arise in commercial laboratory work. Mention is made of some of the fundamental color standardization accomplished and its relationship to commercial duplicating in the independent laboratory.

---

* Presented Oct. 17, 1944, at the Technical Conference in New York.

** New York.

Years ago when color in motion pictures was just a matter of scientific speculation, Thomas A. Edison expressed the thought that the combination of color and sound in motion pictures would represent the highest pinnacle in motion picture technological achievement. By Edison's criterion, it would appear that we have already arrived at that millennium.

As in the case of prior arts, the daydreams of the pioneers became the realities of a later day. The embodiment of a daydream usually brings forth new problems that must be solved in turn. We may view this as the secondary stage in the development of an art. And so it is with integral tripack color films; they are entering the stage of application and intensive secondary technological improvement.

The idea of multilayer films for color purposes traces back to the earlier stages of the motion picture long before sound became a commercial feature. The dye-coupler concept likewise harks back to an early time; its potentialities were appreciated to a remarkable degree as early as 1907. The names of Homolka,[1] Lewy,[2] and Fischer[3] will be remembered as early pioneers with vision.

It has taken a long time for the processes described by these investigators prior to 1914 to become commercial realities. Just as the photoelectric cell had to wait for the coming of electron tubes and amplifiers before sound films could be commercialized, the integral tripack color films had to wait for suitable dyes and other chemicals. As in other fields of invention, each new discovery added to the total store of knowledge and, in turn, each new discovery was found to have its limitations. It appears that there is no solution that will meet all the requirements of an "ideal" color process; there is no "perfect" film or "perfect" process.

Kodachrome Processing and Duplicating: Some History.—Additive processes such as the old Kodacolor process gave way commercially to subtractive processes. No filters or other gadgets are needed for either camera or projector when integral tripack subtractive color films are used; this was considered a "must" for color film for the amateur. Kodachrome—introduced in 1935—is the most widely used 16-mm motion picture color film. It was made simple for the user despite the fact that it was complex in manufacture and in processing. When it was first introduced the developing process included approximately 30 stages, each of which required precise control. The process worked well; amateurs and others bought film, exposed it in their cameras, and projected the results in color.

To an operator of a commercial film laboratory, the requirement that a particular piece of film must go through some 30-odd control stages automatically brings the reaction "I'm glad that it is the manufacturer's problem and not mine." In black-and-white commercial laboratory work we still seem to have considerable difficulty today with but a fraction of that number of control stages.

It was logical to expect the Eastman Kodak Company to simplify such a complex developing process in order to cut operation costs and to reduce the risks of damage during processing. Such simplifications had to be introduced while commercial film was being processed daily; if the customer were to be aware of the difference at all, he should observe it as an improvement. Obviously something in the process had to be "tied down." It is fair to say that the average user was not aware that changes in the process were constantly being made; yet there were unmistakable signs that Kodachrome was improving. There was close control of emulsion manufacture and of color developing as well as coordination between them. The price at which the raw film was sold included the developing cost; there was little opportunity on the part of the manufacturer's laboratory to "pass the buck." (No commercial laboratory attempted to color-develop Kodachrome; no such laboratory regardless of its personnel and equipment could ever hope to operate at a profit under such strict control requirements especially since the developing cost was already included in the price of the raw film and when the process itself was in a "fluid" state.)

Soon after Kodachrome first made its appearance, it was logical to expect that attempts would be made to duplicate it. In the early stages, duplication was little more than placing Type *A* raw film in a contact printer with the original picture and then snapping the switch. The printed film was hopefully shipped to Rochester; occasionally a developed roll with images would return. Oftentimes there was an apologetic letter together with a new roll of raw film.

When commercially usable films started to return with some degree of frequency from Rochester, a commercial duplicating business was born. Even at that early stage the advantages of color and sound in 16-mm were appreciated; a survey of certain industrial film users showed that more than 90 per cent of those canvassed wanted color in their 16-mm sound films—and only Kodachrome was able to give it to them. The rapid growth of Kodachrome duplication, therefore, was not entirely unexpected.

The Available Types of Kodachrome.—Kodachrome for the 16-mm camera is sold in 2 different color balances: Regular, for daylight, code *EK 5263*—balanced for 6100 K source temperature; Type *A*, for Mazda, code *EK 5264*—balanced for 3450 K source temperature. The price at which the film is sold includes color developing.

Kodachrome for duplicating is sold in a single color balance: Duplicating, for 2900 K source temperature, code *EK 5265*. As in the case of Kodachrome for the camera, the price includes color developing. Sixteen-millimeter Kodachrome is designed to be used with a specified arrangement of filters for "balancing" purposes and with the lamp operated at the specified temperature of 2900 K. Further data upon the process will be given later in this paper.

The duplication of Kodachrome has grown in volume to the point where each of several laboratories not connected with the film manufacturer is printing several million feet per year. The total handled by all users is a truly large item when we remember that the average cost is approximately 8 cents per ft compared with approximately $1^1/_2$ cents per ft for black-and-white.

Competitive Positions of Present-Day 16-Mm Color Methods.—It would seem worth while at this point to give some thought to the future as signs point to a still further increase in volume of 16-mm color film. For most purposes, the present Kodachrome product is quite satisfactory. There are several competitive factors, however, that are the imponderables of the future.

First, there is the marketing of Ansco Color Film. At first glance, Ansco Color Film would seem to be in the fortunate position of sharing the future 16-mm market with Kodachrome. Undoubtedly the color printing techniques will be similar. With good sensitometric control, color development should not encounter any very serious obstacles although most prospective users will have to begin to learn what quality control and process control really mean if they hope to be commercially successful. This is a very real and serious problem; even the most optimistic of us would hardly dare to say that good control has been achieved when we screen prints of training films for the Armed Forces.

The second imponderable is sound. The sound quality available with present-day Kodachrome does not compare with the quality obtainable under properly controlled conditions with high resolving power films such as the blue-dyed *EK 5372*, or the yellow-dyed *EK 5365*. (The rated resolving power of both is 150 lines per mm.)

Bruno[4] does not hold out much hope for conventional methods o improvement when he states that both Ansco Color Film and Kodachrome exhibit resolving power of the order of 40 lines per mm. It would seem that the difference between Bruno's measurements and the Kodak ratings can be probably attributed to a difference in measuring technique. It would be desirable to evolve some empirical method for evaluating resolving power. This would avoid apparent discrepancies; to paraphrase Mark Twain, "An argument arises when two people use the same words to describe different things." Possibly 2 figures might be established—one representing the performance of the picture portion of the film (this could establish agreement upon a single visual method), and the other representing the performance of the sound portion of the film. It would seem that the sound art has already reached the point where some such evaluation method could be used for expressing the performance of a sound record when scanned by the scanning beam of a projector. Such evaluations would be useful in comparing the performance of black-and-white with color film; a standard projector will project either.

In a recent issue of the JOURNAL, Görisch and Görlich[5] discuss some of the criteria for a satisfactory sound track on multilayer films and report upon some of their tests. Their conclusion that the usual caesium surface photoelectric cell is well suited to the reproduction of silver-emulsion films, but should be modified with antimony if it is to reproduce dyed films satisfactorily, is significant. No doubt much undisclosed progress has already been made in making the cell to fit the film and the film to fit the cell. While the general trends that the characteristics should take seem indicated, the problem is really a knotty one and will require considerable further thought before it is satisfactorily solved in terms of the high-resolving power of 90 lines per mm required of projection lenses. It may well turn out that the major part of the 16-mm color film market will be initially awarded to the film manufacturer whose product delivers outstanding sound quality as the color problems for the picture seem less difficult of solution.

The third imponderable is picture detail. The loss in detail in a very well-made Kodachrome or Ansco Color duplicate is excessive when we think in terms of lenses with 90 lines per mm resolving power used on projectors with 50 amp on the arc throwing light upon 15-ft screens. Low resolving power is inherent in multilayer films as it is necessary that relatively fast individual emulsions be used for even a slow-speed final product. Bruno[4] reports an immediately available increase from 40 lines per mm to 55 lines per mm if certain sacrifices are made in color rendition. In the making of duplicates, Bruno further reports that the number of filters used in printing will have to be kept to a minimum as there is evidence of considerable loss of resolution (about 10 per cent) for every filter introduced in an imaging optical system.*

The fourth and final imponderable is the competitive position of imbibition printing. (Technicolor is an example.) Where the number of prints in an order runs to 500 or more, imbibition printing should show some very generous profits at the present duplicate bulk price of 8 cents per ft. An additional factor in its favor is that the resolving power problem does not loom so large when compared with integral tripacks. Laboratories that duplicate Kodachrome have experienced 500-print orders, and it is likely that they will fight hard to boost quality as imbibition color printing enters the field as a strong and able competitor.

The foregoing and other marketing factors seem to point to the conclusion that 16-mm color-sound printing will probably become quality-competitive and price-competitive at the same time. Because of the importance of production methods and their influence on production costs, some notes upon the present Kodachrome duplicating techniques are indicated.

Picture Duplication.—The general instructions for making 16-mm Kodachrome duplicates are found in a booklet "Instructions for Making 16-Mm Kodachrome Duplicates on Kodachrome Duplicating Film Code *5265*," Issue No. 8, March 30, 1944. This should be in the hands of all those engaged in the business of making Kodachrome duplicates. It is issued by the Motion Picture Film Department of the Eastman Kodak Co.

The basic method is simple. The lamp in the printer is first set and maintained at the color temperature of 2900 K. The intensity

* The gelatin compensating filters of the CC series supplied by the Eastman Kodak Company for Kodachrome duplicating are considered "optically inert" and do not introduce losses as serious as the more permanent glass filters. They are, however, somewhat unstable when subjected to heat and must be checked periodically when they are used in commercial duplicating. The loss in resolution caused by a particular filter in an imaging system varies quite widely when used in different parts of an optical system. Barring heating and similar deteriorating effects, correction filters are best used over the light source as it is here that they introduce minimum loss in resolution.

is then reduced to the appropriate value by means of neutral density filters or equivalent after the specified printing filters are mounted in place in the light beam.* A test original is then printed; production prints are made after the minor corrections indicated by the test are made. All tests should be made upon the same emulsion lot of film as that which will be used for production printing. Slightly different "balances" will be required for different emulsion lots. In other respects, the printing process is comparable to black-and-white printing.

Some Limitation of the Duplicating Process.—When certain films are duplicated in the specified manner, the result on the screen may leave something to be desired. There are several possible sources:

(*1*) *An accurate copy of the original may not be desired; the color balance of the original may be quite different from that desired in the duplicate.* It often happens that colors "ideal" for Kodachrome are not possible or convenient in the original photographing; photomicrography, where bacteria dyes and stains are involved, is a typical example.

(*2*) *The exposure of the original may be quite different from that desired in the duplicate.* One example would be the exposure required for a short sky shot interposed between 2 shots of dark woodland; such a sequence might be found in a training film dealing with the landing of airborne troops.

(*3*) *The duplicating process itself has limitations.* Some practical duplicating problems cannot be solved satisfactorily by merely following the printed Kodak instructions; they require an understanding of the pertinent limitations of the process.

The Theoretical Elements of the Color Process.—As a starting point, we may say that the color spectrum has been arbitrarily (yet with good reason) divided into 3 major parts. For the purpose of duplicating, a color compensating filter may be considered to provide attenuation in only one part of the spectrum. To provide different amounts of attenuation, each type of filter is made in different densities. For convenience, the color densities can be the same in all 3 parts of the spectrum. We would find, therefore, a series of minus-blue filters, a series of minus-green filters, and a series of minus-red filters. Eastman Kodak has chosen 3 color densities—0.06, 0.12, and

---

* The specified filters are:

2—3.2-mm Aklo (supplied by Kodak)
1—Wratten *2A*
1—Kodak *CC45*
1—Kodak *CC44*
1—Kodak *CC34*

0.22—as the rated color densities for each spectrum part. Since each filter attenuates in only one-third of the spectrum, the equivalent neutral density for a particular color density may be considered one-third of its respective color density. Thus the equivalent neutral densities for the color densities chosen are 0.02, 0.04, and 0.07, respectively. Roughly speaking, the minus-blue (yellow) range extends from 400 to 500 mμ; the minus-green (magenta) range from 500 to 600 mμ; and the minus-red (cyan) range from 600 to 700 mμ. Fig. 1 shows the filters and their ratings in tabular form.

Friedman[6] presents an interesting yet simple discussion of the first-order relationships of what may be termed the 3 components of a 3-color process. Theoretically a set of compensating filters such as those described should be adequate for the purpose according to the criteria for color reproduction set forth. In practice, the Kodak set

Color Density	Attenuation Ranges: 400 to 500 mμ (Minus-Blue)	500 to 600 mμ (Minus-Green)	600 to 700 mμ (Minus-Red)	Neutral Density Equivalent
0.06	*CC23*	*CC33*	*CC43*	0.02
0.12	*CC24*	*CC34*	*CC44*	0.04
0.22	*CC25*	*CC35*	*CC45*	0.07

FIG. 1. Ratings of Eastman color compensating filters for Kodachrome duplicating.

of filters is adequate in most cases, but there is a small number, particularly those cases in which large-order corrections are to be introduced, in which the simplified Kodak procedure leaves something to be desired. A study of the process should explain the discrepancies.

Color Standardization.—As a starting point, we have a standard called "The Specification and Description of Color." This was issued as American War Standard Z44-1942 by the American Standards Association. Section *2.1* reads "The spectrophotometer shall be recognized as the basic instrument in the fundamental standardization of color." A convenient instrument that is commercially available is the General Electric Recording Spectrophotometer. This instrument is widely used; it is available in commercial testing laboratories such as Electrical Testing Laboratories in New York. Curves shown in this paper were taken on this instrument.

Gage[7] reviews color measurement and sets forth some of the terms regularly used to describe the attributes of color. There is a generous list of references at the end of the paper for those who are interested in the many scientific aspects of color.

No discussion of color standardization, however brief, can be considered complete without mention of the ICI Standard Observer and Coordinate System for Colorimetry. Color specifications prepared in accordance with this internationally accepted method can be computed from spectrophotometric data. Unless otherwise specified, standard ICI illuminant *C* (representative of average daylight) is assumed. Results of the computations are expressed in a table of 3 values for each wavelength in the spectrum. These data are then plotted as a curve for convenience. Owing to the computations required, this method of describing color is limited in its use; for most purposes curves taken by the recording spectrophotometer are preferred.

The "Munsell Book of Color" must also be mentioned as a catalog or atlas of color that is in wide use. This book is made up of a large number of color samples. The characteristics of many of these have been measured on the recording spectrophotometer and also translated into ICI terms. The colors in this book were used as a standard prior to 1931 at which time the ICI formulated the present system. The Munsell Book is still of real value as a reference not only because of the great variety of colors included, but also because of the uniformity and the permanence of the materials used for them.

The Textile Color Card Association of America has taken the lead in recommending the use of standard names for colors used in the textile industry. The Association has not only selected suitable names for the colors but has also been analyzing each color spectrophotometrically. It is not uncommon for specifications to describe the colors of radio hookup wire insulation and of color coding of the resistance values of resistors used in radio equipment in terms of the Textile Color Card Association colors.

Mention must also be made of the influence of the graphic arts in color standardization, particularly the "Offset Color Guide" published by the International Printing Ink Division of the Interchemical Corporation. This guide contains over 100 separate test frames (of the same subject) and not only illustrates a large variety of color shades arranged according to dominant color, but also gives the specification for each illustration in terms of both the spectrophotometric and the Munsell color factors in accordance with ASA Standard *Z44*. This booklet represents a convenient and reliable source of color illustrations for color photographing and like tests. Mention must also be made at this point of the "Three Monographs on Color" published by the same company. These volumes are delightful in addition to being scientifically correct. They should be of interest to both scientist and layman alike interested in color in whatever aspect.

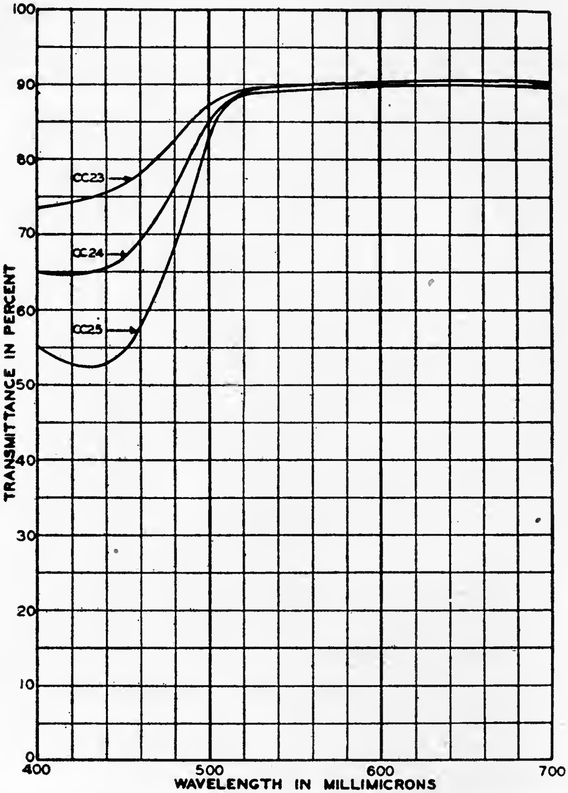


FIG. 2. Transmittance-wavelength characteristics of Eastman minus-blue (yellow) compensating filters.

Color Filter Criteria.—One of the first items to be investigated is the transmission characteristics of the filters used. To the electrical engineer with communications experience, the mention of the word "filters" brings 3 questions to mind:

(*1*) What are the actual transmission characteristics in the pass band?

(*2*) What are the attenuation rates at cutoff and at crossover?

(3) What are the transmission "discontinuities" and irregularities?

The concept of Q is so firmly established in the electrical engineer's mind that he would prefer to think of optical filters in the same manner. Although we have not yet learned how to design optical filters

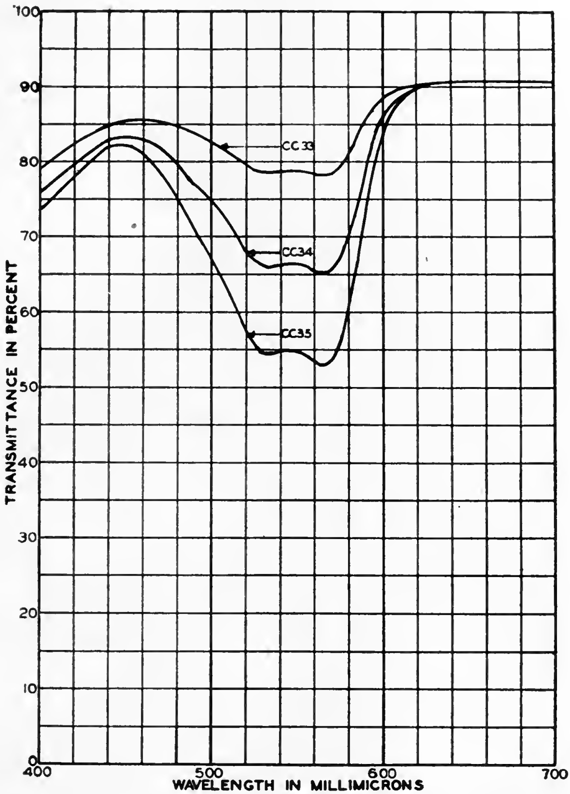


FIG. 3. Transmittance-wavelength characteristics of Eastman minus-green (magenta) compensating filters.

with knobs on them that will permit ready adjustment of their resistance, inductance, and capacitance equivalents, the electrical engineer is not stopped from thinking of their performance in such equivalent terms.

Sources of Filter Data.—Optical filter data are obtained from the catalogs of manufacturers and from such references as the Hodgman-Holmes "Handbook of Chemistry and Physics," familiar to most students of chemistry. Some of the more important catalogs include:

(*1*) "Glass Color Filters," Corning Glass Works, Corning, N. Y. (Form *C247*).

(*2*) "Jena Colored Optical Filter Glasses," Fish-Schurman Corp., New York (*4892E*).

(*3*) "Neue Lichtfilterglaser," Fish-Schurman Corp., New York (*5990g*).

(*4*) "Wratten Light Filters," Eastman Kodak Company, Rochester, N. Y. (16th Ed.).

Data for Filters Used in Kodachrome Duplication.—The per cent-transmission wavelength characteristic of the *2A* Wratten filter is given in "Wratten Light Filters" and the characteristics of Aklo filters are given in "Glass Color Filters," both mentioned above.*

Data for the Kodak Color Compensating Filters have not been published previously; Fig. 2 shows the characteristics for the minus-blue series (*CC23*, *CC24*, and *CC25*), Fig. 3 shows the characteristics of the minus-green series (*CC33*, *CC34*, and *CC35*), and Fig. 4 shows the characteristics for the minus-red series (*CC43*, *CC44*, and *CC45*).

If these various sets of color compensating filters are compared, significant differences are apparent. Although each set represents a "family," only the minus-blue series seems to fit the "ideal" criterion that attenuation shall take place only in the band for which the filter is rated. Even this series does not have a "square wave" transmission characteristic. It would be unreasonable to expect such a characteristic from the coloring materials available for filter making. Since the differences, though small, are significant, it is well to summarize them.

Minus-Blue Series (CC23, CC24, CC25)

(*1*) One principal absorption wavelength—430 mμ.

(*2*) Negligible attenuation in either the minus-green or the minus-red bands.

Minus-Green Series (CC33, CC34, CC35)

(*1*) Two principal absorption wavelengths—530 and 565 mμ.

(*2*) Slightly greater attenuation at 565 mμ than at 530 mμ.

(*3*) Slight attenuation in the minus-blue range (approximately 10 per cent at 430 mμ for *CC35*).

(*4*) Negligible attenuation in the minus-red range.

---

* The 2 pieces of Aklo glass supplied by Eastman Kodak are 3.2 mm. thick. The data given in the Corning catalog for Aklo numbers *3966* (extra light shade), *3965* (light shade), *3962* (medium shade), and *3961* (dark shade) are for a thickness of 2 mm.

Minus-Red Series (CC43, CC44, CC45)

(*1*) Broad band nonsymmetrical transmission centered about 500 mμ.

(*2*) Slight attenuation in the minus-blue band (approximately 15 per cent at 430 mμ for *CC45*).

(*3*) Greater attenuation at 565 mμ in the minus-green band than at 530 mμ (almost 15 per cent).

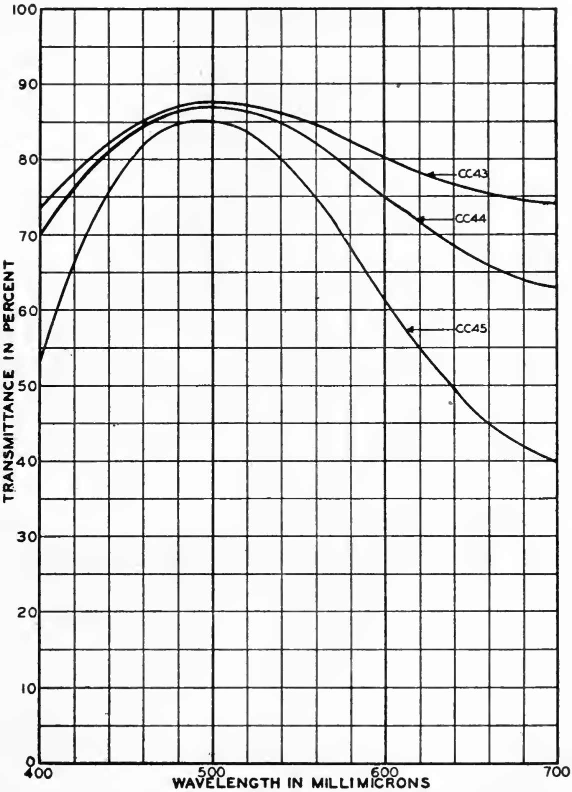


FIG. 4. Transmittance-wavelength characteristics of Eastman minus-red (cyan) compensating filters.

(*4*) Appreciably greater attenuation at the longer wavelength end of the minus-red band than at the shorter wavelength end (approximately one-third greater for *CC45* at 700 than at 600 mμ).

Should it be necessary to use other filters for correction purposes it will be found that it is not convenient to compare quickly the published characteristics of filters made by different manufacturers owing to the differences in the manner in which such characteristics are presented. It is expected that in the near future all manufacturers will use standard scales for published data and standard methods of measurement so that optical filters for photographic purposes may be readily compared regardless of their origin. Progress has already been made in this direction by the War Committee on Photography and Cinematography of the American Standards Association.

Data for Kodachrome Duplicating Film.—The film itself can be checked for deviations from the "ideal." Fig. 5 shows a per cent transmittance versus wavelength characteristic of unexposed developed Kodachrome; for comparison purposes both Type *A* and

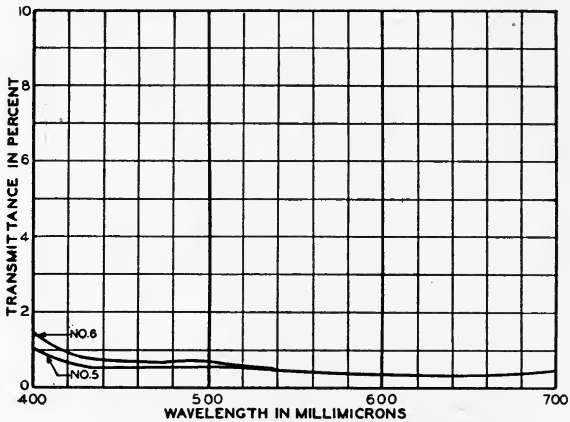


FIG. 5. Transmittance-wavelength characteristics of unexposed and developed Kodachrome: No. 5—EK *5265* (Duplicating); No. 6—EK *5264* (Type *A*).

duplicating Kodachrome are shown. From these curves it is reasonable to conclude that Kodachrome when unexposed provides a satisfactory neutral gray.

The film can next be checked under simulated operating conditions. Fig. 6 shows these characteristics when a fine-grain black-and-white film, which is uniformly exposed (*EK 5365* exposed and developed to a density of 0.5), is printed on a step-contact printer through the basic set of filters recommended by Eastman Kodak for duplication. These curves show that at the exposure used the neutral gray is reasonably well maintained. In addition, they indicate that although *EK 5264* Type *A* Kodachrome requires less exposure than EK *5265* duplicating Kodachrome, the duplicating film has the smoother curve and should be used wherever possible. Among other reasons for preferring it, is the not unimportant factor that the price is appreciably lower.

Contrast Control.—It may well be said that integral tripack duplication makes no provision for the purposeful control of contrast. While it is true that in the earlier stages there was little need owing to the limited useful contrast range, subsequent improvement has brought forth that need.

The problem is a very difficult one with many facets. It means the introduction of still another variable into a process where the number of variables is already large compared with commercial black-and-white processes. At first glance Ansco Color Film would seem to present the possibility in the color developing of the film, but so far there has been little encouragement in this direction. In the case of Kodachrome the need for constant developing is considered very important and it is felt that contrast control is better accomplished in some other manner.

A number of solutions to the contrast control problem has been suggested and a certain amount of laboratory experience has been obtained with one promising possibility—masking film.* So far, the complexities of use are such that it has not been considered suitable for motion picture use although it is well suited for still pictures. No doubt there will be some modification of the basic idea in the future that will be satisfactory. It would not seem impossible to incorporate this in the form of an additional sensitized layer in the duplicating raw stock. Such a layer might have the further advantage of being suitable for the sound record thereby avoiding some of the seemingly insurmountable problems associated with the multilayer color sound track.

Production Quality Control of Prints.—There is much to recommend the routine testing of every roll of film printed. It is necessary

---

* Masking film when so used is an unexposed sensitized thin film cemented or otherwise attached to the developed original Kodachrome picture. Each scene is given a predetermined exposure in a printer and then developed in a black-and-white developer bath, producing a complementary negative of the picture on the masking film as a mask. When the picture is then printed (with the masking film still attached), the contrast of the original is effectively reduced. (Should an increase in contrast be desired, this might be accomplished by developing the masking film as a reversal. It is rare that an increase in contrast is desired; most duplicated films suffer from excessive contrast rather than too little contrast.)

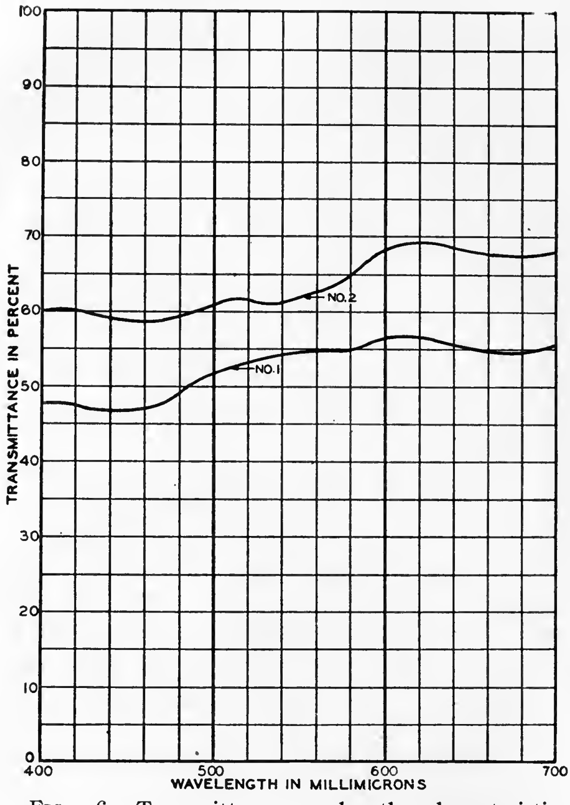


FIG. 6. Transmittance-wavelength characteristics for the Kodachrome duplication of a black-and-white film with EK *5265* and EK *5264*. The conditions of test were: (*1*) Original used: EK *5365* uniformly exposed and developed to a density of 0.5. (*2*) Kodachrome used: No. 1—EK *5265* Duplicating Kodachrome; No. 2—EK *5264*, Type *A*, Kodachrome. (*3*) Filters used: one Wratten *2A*, one *CC45*, one *CC44*, one *CC34*, two 3.2-mm Aklo. (*4*) Light source: *T-10*, 105-v, 500-w lamp at approximately 80 v. (*5*) Printer: DeBrie (contact-step printing at approximately 20 ft per min.)

to establish quality control in printing and to maintain control once it has been established. Routine testing is required for every other element entering into the process. Commercial color duplication in Kodachrome is therefore exacting and demanding, yet interesting work.

The starting point is a lamp, the color temperature of which is known. The color temperature is not known, however, unless the limits to which it has been measured are also known. The same electrical testing laboratories that provide recording spectrophotometer services can also determine the current at which a particular lamp will reach the desired color temperature. If a lot of 50 lamps of the same type is tested, the cost for a measurement within a tolerance of ± 10 K is but a fraction of the cost of the lamp itself. Should seasoning or aging be required, these laboratories can provide such service at very low cost. With such reliable services available at low rates, no commercial laboratory engaged in the duplication of color film, such as Kodachrome, can afford to be without control aids. Fig. 7 shows a color-temperature versus voltage versus current relationship of a typical 500-w, 105-v *T-10* printing lamp. Other valuable lamp data are found in the bulletin "Mazda Lamps."[8]

Exposure is most readily measured directly at the printer aperture with the machine stationary; the better grade illuminometers such as the Weston Model *628* (priced approximately $100) are suitable. Indirect methods, such as the use of black-and-white film as a control, are not practicable in most commercial laboratories as they introduce additional variables whose variations are usually unknown.* In using illuminometers and similar direct-measuring instruments, it is necessary to make up suitable jig-adapters so that readings of the instrument will be reproduced without significant personal error. Provision should also be made for periodically calibrating the measuring instruments. It is necessary that the variation in slip of belt-driven printers be known. It is still better to use direct-gear drive with a 3-phase synchronous motor or equivalent to eliminate machine speed variation as a possible source of exposure variation.

---

* Such indirect methods can be satisfactory if the sensitometric control on black-and-white is of a superior order compared with usual commercial control. In such cases, however, the direct methods are still more convenient and more precise.

The regulation of the current supply for the printing lamp is very important. It is obviously a sheer waste of time and money to calibrate lamps to ±10 K when the motor generator or other supply has poor regulation, and other loads are indiscriminately "placed on the

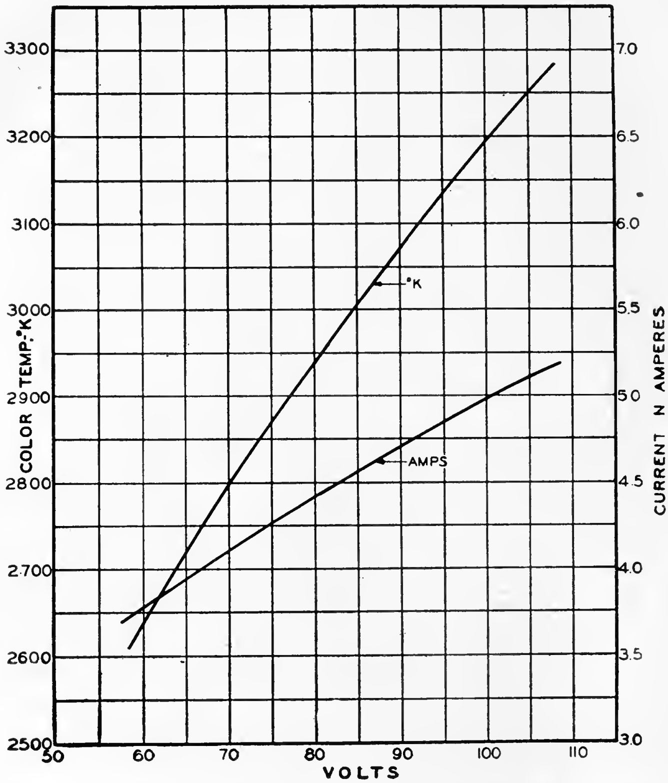


FIG. 7. Typical color temperature-volts-amperes characteristics of a 500-w, 105-v *T-10* lamp.

line" and "taken off." A simple check is to connect a recording voltmeter to a printer under suspicion, using that printer without current changes meanwhile. Often the local power company will be glad to lend a suitable meter if one is available.

From the user's point of view, Kodachrome duplicating film (EK *5265*) is quite consistent. The major variation that occurs is the variation from lot to lot, similar to that occurring in black-and-white materials. With fresh film, the variation in sensitivity from one lot to another appears to be less than one of the smallest compensating filter steps (*CC23*, *CC33*, or *CC43*). The variation in layer sensitivity from one layer to another appears to be likewise small and of comparable order. For film that has aged slightly (for example, less than 6 months old when stored at a constant temperature not over 70 F), there is a slight loss in speed and a slight change in color balance, but the sum total of such variations does not appear to exceed the equivalent of the single filter step already mentioned. When film has been improperly stored or is old it is likely to be "off balance" by more than a single filter step. It is prudent to make an exposure and color balance test not only for every emulsion lot of film received, but also on every lot received at different times. A log with the results of such tests quickly shows up not only errors and variations, but also indicates when properly interpreted the magnitude of the exposure variation actually encountered in printing the tests.

Routine testing of filters in the arrangements in which they are used is helpful. The cost for several curves is no more than the price of a single 800-ft roll of raw film. Testing of this kind is in reality inexpensive quality insurance.

Routine testing of the duplicates made commercially is readily accomplished if a test strip is attached to every roll of preprint material and printed as a part of the routine printing operation. The test strip can be designed to fit whatever situation is required. A simple yet informative test leader might include a few frames of each of the following:

(*1*) A fine-grain silver film (such as EK *5365*) uniformly exposed to a density of 1.0.

(*2*) Clear leader (made by running EK *5365* through hypo).

(*3*) The 16-mm Kodak color test chart.

(*4*) Kodachrome printed through a Wratten *49* (blue filter) to yield a color density of 1.0.

(*5*) Same as (*4*) except through a Wratten *61* (green filter).

(*6*) Same as (*4*) except through a Wratten *29* (red filter).

(*7*) A resolving power test chart.

The test strip should be printed at "normal" exposure for the particular lot of raw film.

Sections *1*, *2*, *4*, *5*, and *6* can be read with an ordinary Capstaff-Purdy (EK Co.) densitometer. The results of these readings can be plotted in a "scatter diagram" in accordance with the methods described in ASA Standards for Quality Control, *Z1.1*, *Z1.2*, and *Z1.3*. A check lasting over even a few weeks will indicate where the "tightening-up" process should be applied for quality improvement and in what amounts it should be applied. If more accurate results are required in specific cases, other checks such as per cent-transmittance versus wavelength curves may be taken on the pertinent parts of the printed strip.

Conclusion.—Integral tripack films such as Kodachrome are good materials in good control at the present time. It must be remembered, however, that there is no "perfect" color process. The usual requirements of a color process are:

(*1*) A suitable gray scale,
(*2*) Comparable color scales for the components,
(*3*) Accurate reproduction of color,
(*4*) Good differentiation of color.

Each of these requirements conflicts in some measure with at least one of the other three. Ordinarily (*1*) and (*4*) are favored over (*3*).

The most recent edition of "Photomicrography" (1944) carries the admonition concerning photometric filters in these words, "There are no colored pigments or dyes actually available for making the three colored components of a picture that do not absorb light outside of their own spectral domain and thus degrade the hues of the final result".[9] Curves are essential in describing the performance of filters for color duplicating purposes.

For convenience, wavelengths shorter than approximately 420 mμ are filtered out of the exposing illumination. This is accomplished with the Wratten *2A* filter or equivalent. The near ultraviolet and the shorter blue rays increase the exposure in the blue layer, but as it is not practicable to evaluate this exposure accurately by either an illuminometer or by the indirect film method, it is usually better to remove these wave lengths from the light beam. With these wavelengths removed, results are usually more reproducible.

Generally speaking, colors that have components in the filter crossover regions of 500 mμ and 600 mμ are difficult to control for accuracy of color reproduction. In most practical cases good color differentiation will suffice and such filters as the Corning *5120* (light didymium) and its approximate equivalent, Jena *BG11*, in moderate thicknesses, such as 1 mm and 2 mm, are often quite useful. These filters are likewise helpful in retaining face and skin detail in a duplicate that is printed from a slightly overexposed original, as well as in the reproduction of certain biological stains and dyes[9] whose absorption points are "unfortunately" located.

It should be remembered that even a "perfect" copy is of little value if the print is not projected properly. The importance of correct illumination level can hardly be overemphasized. At present, even when screen illumination is in the uppermost range found in practice, it is rarely within 20 per cent of what might be called the optimum value. Because screen illumination is of such a low general order, film laboratories have often deliberately chosen to overexpose duplicates in printing, thereby wiping out much detail and further aggravating an already serious condition of low resolving power. The magnitude of this effect can be roughly judged by comparing the detail and quality of a Technicolor picture projected in a neighborhood theater with the usual 16-mm projection of a Kodachrome duplicate. Such a comparison is reasonable; several Technicolor releases have been made from 16-mm Kodachrome originals. There are other factors, but these are beyond the scope of this paper.

Although the Eastman Kodak recommended method of duplicating Kodachrome is relatively simple and places the major part of the control burden upon the film manufacturer, it is imperative that the commercial laboratory accept its share of the control responsibility knowingly and willingly, and appreciate the importance of process control by applying some of its basic principles. The control of emulsion quality in manufacture and the control of color developing have reached such a high point that it is no longer possible to indiscriminately "pass the buck" to the film manufacturer if prints do not come up to expectations. If the control required for good color duplication according to today's standards were applied to the release printing of the mass-produced prints of Armed Forces training films, the result would be beyond our fondest dreams. This, however, is putting the cart before the horse, for we must first learn to control the single parameter of good monochrome successfully before we can expect to be successful with the 3 parameters of integral tripack duplication. This is a challenge to all concerned; a rapidly growing industry will be awarded as the prize to those who produce the best product at the lowest price.

REFERENCES

[1] HOMOLKA, B.: *Brit. J. Photog.*, **54** (1907), pp. 136, 196, 216.

[2] LEWY, E.: German Patent No. 250,647 (1909).

[3] FISCHER, R.: *Brit. J. Photog.*, **60** (1913), p. 595; English Patent No. 15,055 (1912).

[4] BRUNO, M.: "Maps on Microfilm," *J. Soc. Mot. Pict. Eng.*, **XLI**, 5 (Nov., 1943), p. 423.

[5] GÖRISCH, R., AND GÖRLICH, P.: "Reproduction of Color Film Sound Records," *J. Soc. Mot. Pict. Eng.*, **43**, 3 (Sept., 1944), p. 206.

[6] FRIEDMAN, J. S.: "Monopack Processes," *J. Soc. Mot. Pict. Eng.*, **42**, 5 (May, 1944), p. 274.

[7] GAGE, H. P.: "Color Theories and the Inter-Society Council," *J. Soc. Mot. Pict. Eng.*, **XXXV**, 4 (Oct., 1940), p. 361.

[8] GENERAL ELECTRIC CO.: "Mazda Lamps—Bulletin LD-1," Second Printing (Sept., 1940), p. 38 (Cleveland, Ohio).

[9] EASTMAN KODAK CO.: "Photomicrography," (1944 Edition), p. 151 (Rochester, N. Y.).

PRELIMINARY REPORT OF ACADEMY RESEARCH COUNCIL COMMITTEE ON RERECORDING METHODS FOR 16-MM RELEASE OF 35-MM FEATURES*

WESLEY C. MILLER**

Summary.—*This report details the progress to date in the improvement of the release print quality of 35-mm features reduced to 16-mm, which has resulted from the work of the Academy Research Council Committee on Rerecording Methods for 16-Mm Release of 35-Mm Features. It also describes the new 16-mm test film for field checking projector adjustment prepared by the Research Council in accordance with American War Standard Specification Z52.2-1944.*

The Research Council of the Academy of Motion Picture Arts and Sciences organized its Committee on Rerecording Methods for 16-Mm Release of 35-Mm Features on February 17, 1944, with Wesley C. Miller as chairman. The committee was assigned first, to investigate the procedures then used in making 16-mm release prints from 35-mm originals and to determine the characteristics of the equipment used in reproducing these prints, and second, to effect an improvement in 16-mm release print quality.

In investigating procedures and equipment then used, excerpts from a number of 16-mm release prints were seen and heard on several makes of projectors and on different projectors of the same make. It was very obvious that the quality, especially the sound, was extremely poor and very often not commercial. In many cases a great part of the dialogue, especially low-level passages, could not be understood or even heard.

The poor sound quality was attributable to 3 factors; first, inadequate reproducing equipment; second, inadequate processing facilities; and third, a release print characteristic designed for 35-mm release.

Compared to 35-mm equipment, present 16-mm equipment has poor film motion, limited frequency response, insufficient amplifier capacity, and horn systems of low efficiency which are inadequate

---

* Presented Oct. 17, 1944, at the Technical Conference in New York.

** Metro-Goldwyn-Mayer Studios, Culver City, Calif.

for the purpose of reproducing prints with 35-mm characteristics. This is not the fault of the equipment as it is being used under conditions and for purposes for which it was not designed. Existing 16-mm equipment has been designed primarily for amateur or semi-professional use with small audiences, and to project prints with a comparatively narrow volume range. However, it is being used in large auditoriums and with the projector in the auditorium but without facilities to reduce projector noise. As a result, auditorium noise level is high and the volume range which the equipment can handle is thereby restricted still further. However, this equipment was in the field and in use and could not be improved or replaced immediately. This condition will be improved when projectors in accordance with the American War Standard Specification for Class I Service Model 16-Mm Sound Motion Picture Projection Equipment, Z52.1–1944, reach the field.

Laboratory equipment and procedures did not keep pace with requirements for obvious reasons. Sufficient new equipment could not be purchased under war conditions. Test equipment was often on priority and not available. Present procedures were set up under adverse conditions because of the tremendously increased use of the 16-mm film. Sufficient time, materials, and manpower were not available for proper study and coordination. Since that time, this phase of the work has been coordinated by the ASA War Committee on Photography and Cinematography and improvements have been, and are still being, made.

At that time the general procedure in obtaining a 16-mm release print sound track was to make a photographic dupe of the 35-mm release print sound track. Thus, subject to the printing and processing procedure and the limitations of the reproducing equipment, the release characteristic was based on the 35-mm release and had a comparable volume range and frequency characteristic.

As it was not feasible to replace existing 16-mm reproducing equipment, or make immediate improvements in the laboratory situation, it was decided as a temporary expedient to fit the release print to the reproducing equipment. This meant an apparent reduction in quality of the sound track as it existed on the release print but a net improvement in the reproduced quality, to be provided by reducing the volume range and altering the frequency characteristic of the 16-mm release track.

It might seem that the obvious thing to do was to set up a standard recording characteristic based on the characteristic of 16-mm reproducing equipment. However, this is not practicable. It would not be feasible even if a standard reproducing characteristic could be established.

There are a great number of variables affecting the recording characteristic. It must often be adjusted to the voice characteristic of the actor or actress. It depends upon the type of production being recorded, set acoustics, the type of microphone, and before the release track is made, on the volume range used in the production and on the effect desired by the producer. Various methods are therefore used depending on equipment and technique, to arrive at a release characteristic for the theater. It should be pointed out that in 35-mm work, although various methods are used, and although no standard recording characteristic has been established, all product released to the theater is commercial and the quality has improved steadily over the past few years.

An additional factor influencing this decision of the Committee was the fact that the group had under consideration 16-mm release material from original 35 mm. This original 35 mm is made for commercial distribution. Obviously, it was not possible to alter the recording or release characteristic of the 35-mm product to adapt it to the limitations currently existing in the 16-mm field.

Listening tests on different types of 16-mm equipment and on different projectors of the same make demonstrated that the characteristics of the amplifiers and speakers varied greatly and gave widely different results. The use of tone controls also added a variable in the reproducing characteristic.

As a result, the Committee, with all of the above variables in mind, set out to determine upon a rerecording characteristic.

As all of the studio group are familiar with the Research Council's Theatre Sound Test Reel, this reel was used as a basis for 16-mm test material. For those not familiar with this reel, it contains excerpts from feature release prints from all of the major studios, each sample being processed by that studio's laboratory and these samples spliced together to make the final complete reel. It thus provides a test film exemplifying release quality. This film is used to conduct listening tests in auditoriums and to adjust the equipment to optimum conditions.

Using a 35-mm print of the Theatre Sound Test Reel, the following 16-mm test tracks were made as indicated:

(1) A 16-mm photographic dupe.

(2) A 35-mm variable-density negative rerecorded from the release print sound track. This special negative was used to make a 16-mm print by the optical reduction method.

(3) A 35-mm variable-area negative rerecorded from the release print sound track. A 16-mm optical reduction print was made from this negative.

(4) The 35-mm release track rerecorded to a 16-mm variable-density negative. A 16-mm contact print was made from this 16-mm negative.

(5) The 35-mm release track rerecorded to a 16-mm variable-area negative from which was made a contact print.

These tests provided a 16-mm print made as a photographic dupe, 2 variable-density prints containing material originally made as 35-mm variable density and variable area, and 2 16-mm variable-area prints from material originally 35-mm density and area. The same 35-mm print was used in each case as a rerecording print.

All rerecordings were made with a reduced volume range and a restricting frequency characteristic. In general, the frequency characteristic was sloping on the low end with the low-frequency cutoff in the neighborhood of 100 cycles. The characteristic was peaked in the intelligibility range and the high-frequency cutoff in the neighborhood of 5500 cycles.

After these tests had been prepared, several meetings were held and listening tests conducted in different auditoriums as well as out of doors, again using several different 16-mm projectors. As a result of this second group of listening tests, a rerecording characteristic was tentatively decided upon and additional test recordings made. These test rerecordings were made on the basis of this rerecording characteristic, altered slightly depending upon the type of product being rerecorded.

Following additional listening tests, recommendations were made by the Research Council to the producing studios as follows:

(1) That an especially rerecorded negative be provided for all features and short subjects produced for 35-mm release but reduced to 16-mm for distribution overseas.

(2) That the volume range of the 16-mm release should be compressed to approximately 15 db on the basis that the present 35-mm release print volume range is approximately 35 db. This means that main title and montage music and dialogue peaks should be rerecorded at full modulation. Any signal rerecorded at a level of more than 15 db below full modulation will probably not be audible when reproduced except under the most favorable conditions.

(3) That the following rerecording characteristic be used as a guide (Fig. 1): Low-frequency cutoff—100 cycles; high-frequency cutoff—5000 cycles; a re-

duced response below 1000 cycles; and an increased response of approximately 3 db at 3500 cycles. The resulting characteristic slopes smoothly from 3 db up at 3500 to approximately 6 db down at 200 cycles.

(*4*) That for 16-mm variable-area release the rerecording be either to 35-mm or directly to 16-mm, but whichever process is employed separate sound and picture negatives be used in making the 16-mm release print. Separate film is recommended as the picture and sound negative require different processing for the best results.

(*5*) That for 16-mm variable-density release the rerecording be to a 35-mm sound negative. From this negative and through the optical reduction process is made a 16-mm release print sound track. At the time this recommendation was

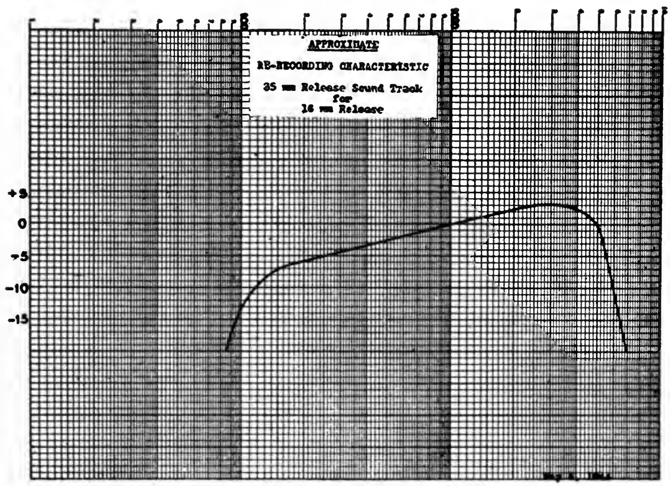


Fig. 1

made recording and laboratory equipment and facilities were not available to provide other than test rerecordings directly to 16-mm.

(*6*) That the rerecording be done from the regular domestic release print sound track as an expedient to produce a reasonably good result at a low cost.

The above recommendations were made in the nature of a progress report as the rerecording characteristic recommended and the methods employed were of a temporary nature subject immediately to any improvements in projection equipment and adopted to effect an immediate improvement in 16-mm feature release quality.

The rerecording characteristic was established only as a rough approximation of the slope of the equalizer curves and the cutoffs recommended. In recommending this rerecording characteristic, the Committee emphasized that it was approximate and temporary and its use depended upon the type of product being rerecorded. Listening tests had demonstrated that different types of product require different treatment.

Since these recommendations were made, the same rerecording characteristic is being used subject to any modification necessary considering the type of material being rerecorded. For variable density the domestic release print sound track is being used as rerecording print to make a special rerecorded negative. A print of this negative is optically reduced to furnish a 16-mm negative from which contact prints are made. For variable-area release the domestic release print sound track is rerecorded directly to a 16-mm negative from which contact prints are made.

During the time this work was going on, both the Research Council and the Society of Motion Picture Engineers were represented on the ASA War Committee on Photography and Cinematography. As a part of this work, the Society took on the job of making available many types of 16-mm test films. The Research Council was asked to make available a 16-mm test film comparable to our 35-mm Theater Sound Test Reel. [A print of this 16-mm reel was projected after the paper was read—*Ed.*] This reel consists of an explanatory title with main title music, excerpts from feature productions released on variable-density track, and a piano recording and excerpts released on variable-area track. This test film is known as the "16-Mm Test Film for Checking Projector Adjustment" and has been prepared by the Research Council in accordance with American War Standard Specification, Z52.2–1944. The specification was prepared in draft form by the Council at the request of Z52 Subcommittee *B* on 16-Mm Sound and was recommended for approval as an American War Standard by that Subcommittee with only minor editorial changes. The specification for the test film was promulgated as an American War Standard on October 11, 1944.

The variable-density track was made as follows: The 35-mm release print sound track was used as a rerecording print to make a 35-mm variable-density negative. In the rerecording process the volume range was reduced and the frequency range restricted in accordance with the rerecording characteristic given above. A compressor was used in the circuit to automatically control peaks with the amount of compression determined by the material in each sample. Previous tests had demonstrated that manual control of the volume range was not too satisfactory. In rerecording for 16-mm feature release, a compressor may or may not be used in the rerecording circuit, depending upon the type of product and the technique used.

A print of this 35-mm rerecorded variable-density negative was optically reduced to provide a 16-mm negative from which contact prints were made.

The variable-area release print tracks were rerecorded directly to a 16-mm negative, again employing a reduced volume range and a restricted frequency range and using a compressor in the rerecording circuit. This negative was used to make 16-mm contact prints.

Thus the 16-mm sound release negative from which these release prints are made consists of a variable-density negative from original 35-mm variable-density and a 16-mm variable-area negative made from original 35-mm variable-area material.

We would like to point out that the Committee deliberately chose this rerecording characteristic with full knowledge that it is possible to obtain better sound quality with a different characteristic if projecting on good 16-mm equipment in a room with reasonably good acoustics. Under such conditions more low-end would be used and the volume range increased. However, it has been found that quite a few projectors are being used with speakers having a low-frequency resonance which tends to mask out the intelligibility. Tone controls are not always used to the best advantage and many instances have been encountered where the tone control has been set to cut out the highs again reducing the intelligibility. Projection conditions are very often adverse as the equipment may be used out of doors or in rooms with poor acoustics and high noise level. Consequently, we believe that the characteristic decided upon is safer than the characteristic with more low-end although in some instances and under favorable conditions the quality would be improved. A wider volume range under good projection conditions would, of course, be preferable to the volume-range of the projector test film, but it has been the sole purpose of the Committee to arrive at the characteristic giving the maximum amount of intelligibility throughout a picture so that the dialogue can be heard and will be intelligible under all conditions.

Accompanying each print of this test film is an instruction sheet briefly describing the use of the reel. This instruction sheet includes a general description of the contents of the film, the procedure in using the film, and the manner in determining the cause of operating troubles if they exist.

This projector test reel is marked *Issue No. 1* as it is expected that the rerecording characteristic will be revised both to improve the reel and to keep in step with advancements in the 16-mm field.

Since the Committee was formed, in February, 1944, all of the producers of feature releases have agreed to rerecord for 16-mm releases where necessary. One studio was rerecording at the time the Committee was formed. At least 3 others were rerecording within 90 days after the formation of the Committee. Thus, since July, 1944, a very definite improvement has been made in the release print sound quality of a large amount of feature product which has been released on 16-mm for distribution overseas. Although the Committee's work is not finished, it has accomplished practical results in a relatively short time in bringing about this improvement in release quality and in making available a 16-mm projector test film.

[**Ed. Note.**—*Since the presentation of this Report, and during the past few months, equipment has become available for rerecording directly from the 35-mm version to a 16-mm release negative. Some recent pictures have been released by this method and it is probable that this will ultimately become the standard method as it eliminates any irregularities which may occur during the process of optically reducing from 35-mm to 16-mm sound tracks.*

Also, it should be noted that the Report applies primarily to black-and-white releases. A similar study on color 16-mm releases has been under way although it was somewhat delayed on account of the different problems presented by the color processes. A full report on this phase of 16-mm release work is contemplated as soon as practicable.]

THE CALCULATION OF ACCELERATIONS IN CAM-OPERATED PULL-DOWN MECHANISMS*

EDWARD W. KELLOGG**

Summary.—*The maximum force between a cam and its follower depends on the mass of the driven elements and the maximum accelerations imparted to them by the cam. The magnitudes of these forces affect the wear on the surfaces and the tendency of the mechanism to be noisy. If the follower works on one side of the cam only, contact being maintained by a spring, the required spring tension is determined by the acceleration. Some cams can be designed to give a predetermined motion and if the motion can be simply expressed mathematically, the acceleration can be easily calculated. Other types of cam are made up of a series of circular arcs and the motion of the follower is determined by certain geometrical relations.*

For any given design, the position of the follower can be calculated point by point of the cam rotation, by solving triangles, or graphically. But to determine velocities by measuring slopes of the position curve, and accelerations by measuring slopes of the derived velocity curve, gives only rough approximations. Determination of velocity by writing and then differentiating a mathematical equation for follower position in terms of cam position, appears to be possible only for the simplest case, but if the problem is taken in 2 steps, first to find the follower position by the solution of one or 2 triangles, and then for a given position, to find the velocity and acceleration from formulas given in the paper, the calculations are not difficult, and the degree of precision may be whatever is required.

Anyone who has tried measuring slopes of plotted curves for such purposes as determining velocities or accelerations realizes that the method gives very crude results. In the course of a study of claw motion for projector pull-downs it was desirable to find whether a certain arrangement which shortens the pull-down time resulted in objectionably large forces against the cam. The graphical method yielded answers which looked unreasonable, and a more accurate method was sought.

The reader might appropriately ask at this point whether a cam can not be designed to give almost any desired relation between cam and follower positions, and can not the movement curve be chosen in accordance with some simple mathematical law for which the accelera-

* Presented Oct. 18, 1944, at the Technical Conference in New York.

** RCA Victor Division, Radio Corporation of America, Indianapolis, Ind.

tions are known to be within specified limits? This is true in general of cams with cylindrical or roller followers. The cam is laid out by making a series of drawings to scale, each of which shows the cam follower in a new position relative to the cam, and the cam surface is the envelope of the series of arcs which represent the successive outlines of the follower. This is illustrated in Fig. 1.

On the other hand, there are important types of cam in which the designer has less freedom. For example, in the Geneva movement (which in principle can be considered to be a cam) the movement

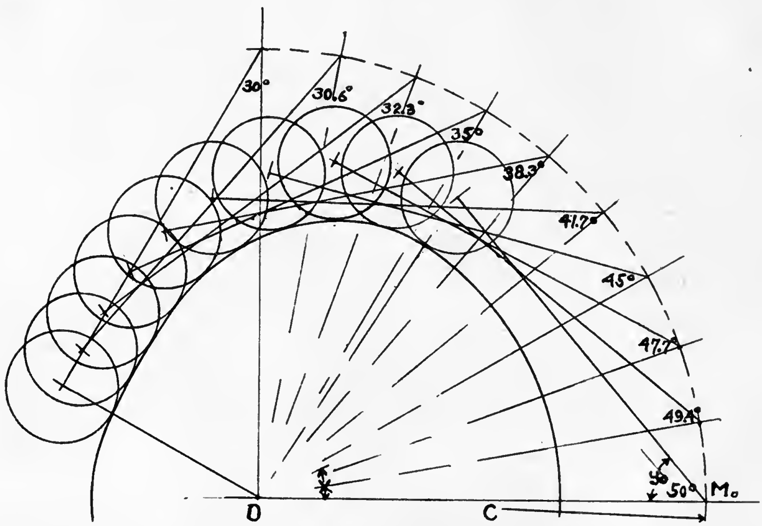


FIG. 1. Method of laying out cam with roller follower to give 20-degree swing of follower arm in 90 degrees of cam rotation—sine wave movement.

of the star-wheel is completely determined by the spacing of the shafts and the radius to the pin. Another important type is the constant-diameter cam, illustrated in its simplest form in Fig. 2. This employs a flat follower, which is an advantage on the score of simplicity and distributed wear. The constant-diameter feature permits operating the cam between 2 parallel flat surfaces, thus giving positive drive at all times and making use of a spring unnecessary. If the cam follower does not swing, but maintains the sliding surfaces in a fixed direction—for example, if the follower slides on a rail—its motion can be very simply stated. Motion begins when the line O–P_1 passes the vertical ($x = 90$ degrees), and thereafter the upper follower surface moves down with P_1, giving a displacement from the starting position equal to $A(1 - \sin x)$ until line D becomes vertical, after which the upper slide rests on the arc S_1–S_2, whose center is P_2, and which is D above P_2. The motion now depends on the movements of P_2, the second half of the curve being identical in shape with the first half. The displacement, velocity, and acceleration curves for the case of $A = 1$ and $\theta = 60$ degrees are shown in Fig. 3. It will be noted that the acceleration is a small portion of a sine curve and then reverses suddenly to equal values of retardation.

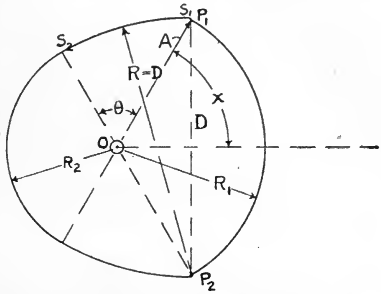


FIG. 2. Constant-diameter cam in its elementary form.

It is obviously not desirable to make the cam with sharp corners. Hence each radius is increased by a small addendum r, giving a small arc of radius r at the previously sharp corners, as shown in Fig. 4. This increases the over-all diameter of the cam by $2r$, but with a parallel-motion follower does not alter the follower motion at all, and with a pivoted follower the motion is the same, provided the follower surface is displaced so that if extended, instead of passing through the pivot point, it would pass above it by the same distance that the cam surface is above P, namely by r.

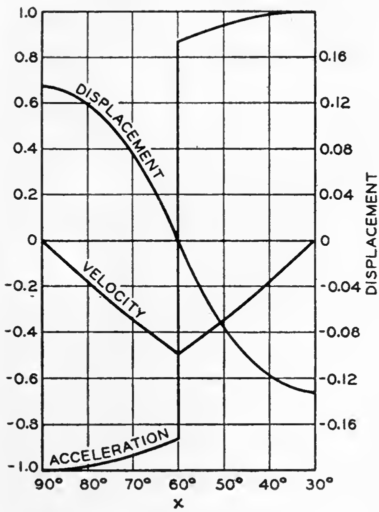


FIG. 3. Characteristics of cam shown in Fig. 2. or 4, with $A = 1$ velocity and acceleration for cam rotating one radian per sec.

In most applications of the constant-diameter cam the follower is pivoted at a short distance from the cam shaft, with the result that there is simultaneous rotation of both cam and follower. This has the effect of shortening the time of one movement of the follower and lengthening the time of the reverse movement. For example, if the action angle θ (in Fig. 2 or 4) is 60 degrees, and if the follower makes a swing of 5 degrees, it will execute one movement in 55 degrees of cam rotation and the reverse movement in 65 degrees. Advantage may be taken of this relation to shorten the pull-down time. The required diameter of the cam for a given throw (difference between the larger and the smaller radius) varies approximately as the inverse square of the action angle θ, or in other words, quickening the pull-down means enlarging the cam. Hence there is generally good design reason for shortening the pull-down time by the expedient just described, but it is desirable to ascertain whether this is being done at the cost of undesirably large acceleration forces.

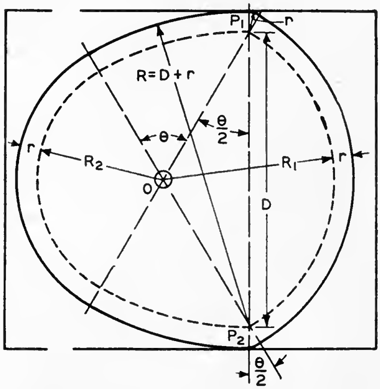


FIG. 4. Constant-diameter cam with addendum to give rounded corners.

If the follower pivot is to the right of the cam, for quick pull-down the cam would rotate clockwise (*i. e.*, x decreasing with time) and in deriving formulas the increments dx and dy are here drawn in this direction, and marked negative for mathematical consistency; $\frac{dy}{dx}$ is the rate of rotation of the follower compared with that of the cam (which is in general constant).

To simplify the problem the cam is assumed to be as shown in Fig. 2 (*i. e.*, $r = 0$). During the first half of the movement the flat follower B pivoted at M, Fig. 5, rests on the corner P_1 which moves in an arc of a circle of radius A, about cam shaft center O. The determination of y requires only the solution of a triangle (see Fig. 6), with 2 sides (radius A and center distance C) and the included angle x given. The simplest procedure is to assume z, calculate y from the formula that the sines of the angles are in the same ratios as the sides opposite them,

$$\sin z = \sin (x + y) = \frac{C}{A} \sin y \qquad (1)$$

and from the relation that $z = x + y$, find x.

We can differentiate both sides of Eq (1) with respect to x and then solve for $\frac{dy}{dx}$, but the geometrical approach now to be explained gives it in simpler form, and is moreover applicable to the second case, or part of the problem, which is more complicated.

For any given cam position (designated by x) if we know the corresponding value of z (or $x + y$) and y, it is quite a simple matter to find the rate of change of y when x changes at a specified rate. Referring to Fig. 6, if x changes by a very small angular negative increment $-dx$ (expressed in radians), the point P_1 will move a distance $-Adx$ in a direction perpendicular to A. Let this movement of P_1 be

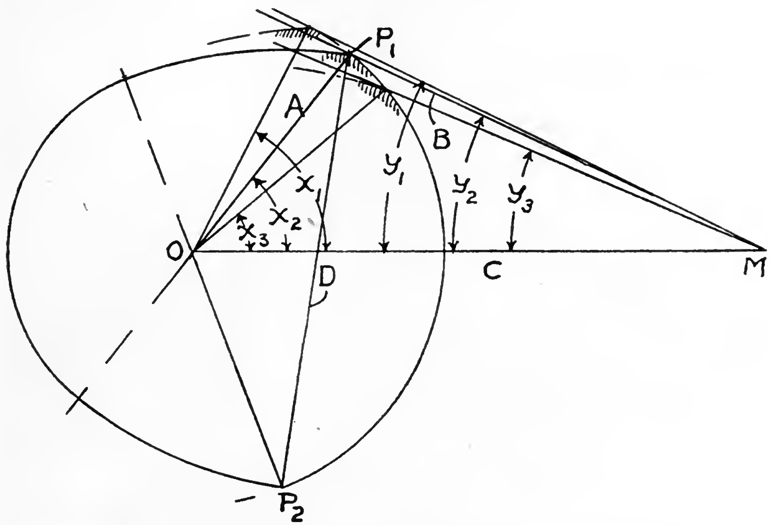


FIG. 5. During the time that follower B is resting on corner P_2 the relation between x and y is determined by solution of a triangle with 2 sides A and C constant.

divided into 2 components $-Adx \sin z$ and $-Adx \cos z$, parallel and perpendicular to B, respectively. It is evident that the part of the movement of P_1 in line with B will not change y, while the perpendicular component $-Adx \cos z$ will decrease y by the angle $-dy = \dfrac{-Adx \cos z}{B}$. In the limit it makes no difference whether we divide by B or by $B - Adx \sin z$. Hence

$$\frac{dy}{dx} = \frac{A}{B} \cos z \qquad (2)$$

which gives the ratio of angular speed of the follower to that of the cam.

To find the rate of change of follower angular speed we differentiate $\frac{dy}{dx}$ with respect to x. Both z and B are variables depending on x. and differentiating the expression as a fraction

$$\frac{d_2y}{dx^2} = A\left(\frac{B\frac{d}{dx}(\cos z) - \cos z\frac{dB}{dx}}{B^2}\right) \tag{3}$$

$$\frac{d}{dx}\cos z = -\sin z\frac{dz}{dx} = -\sin z\left(1+\frac{dy}{dx}\right)$$
$$= -\sin z\left(1+\frac{A}{B}\cos z\right) \tag{4}$$

Referring to Fig. 6,

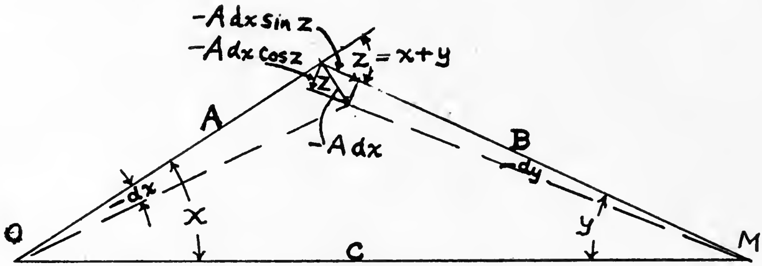


FIG. 6. Components of $-Adx$ parallel and perpendicular to B.

$$-bB = -A\ dx \sin z$$
$$\frac{dB}{dx} = A \sin z \tag{5}$$

Then substituting (4) and (5) in (3)

$$\frac{d_2y}{dx^2} = \frac{A}{B^2}\left\{-B\sin z\left(1+\frac{A}{B}\cos z\right) - A\sin z\cos z\right\} \tag{6}$$

$$= \frac{-A}{B}\sin z - 2\frac{A^2}{B^2}\sin z\cos z \tag{6'}$$

From a consideration of Fig. 5, it will be evident that the problem just considered is applicable to the case of a Geneva movement, the point P_1 representing the center of the pin, and the line B corresponding to the center of the slot in the star-wheel. For the usual 90-degree Geneva movement x varies from $+45$ to -45 and $C = \sqrt{2}A$. Fig. 7 shows the calculated star-wheel velocities and accelerations, referred to the angular velocity of the pin wheel. For any given value of the pin-wheel speed n revolutions per sec, $\frac{dy}{dx}$ should be multiplied by $2\pi n$

to give star-wheel angular velocity in radians per sec, and $\frac{d_2y}{dx^2}$ multiplied by $(2\pi n)^2$ to give angular accelerations.

We have so far dealt with only the simpler part of the calculation of motion in the case of the constant-diameter cam with pivoted follower. For half the stroke the follower rests on the corner, Fig. 2 (or on a small-radius arc just outside it, the error in assuming contact at the corner being small unless r is larger in relation to C than is ordinarily the case). After the line D, in Fig. 2, passes the position perpendicular to follower B, the latter no longer rests on the corner but on the arc S_1–S_2 of which P_2 is the center, as indicated in Fig. 8. Thereafter the calculation of y requires the solution of 2 triangles, OMP_2 in Fig. 8, to find u and E, and then the right triangle P_2TM to find $u + y$ and B. It is scarcely necessary to include here the steps of calculating y.

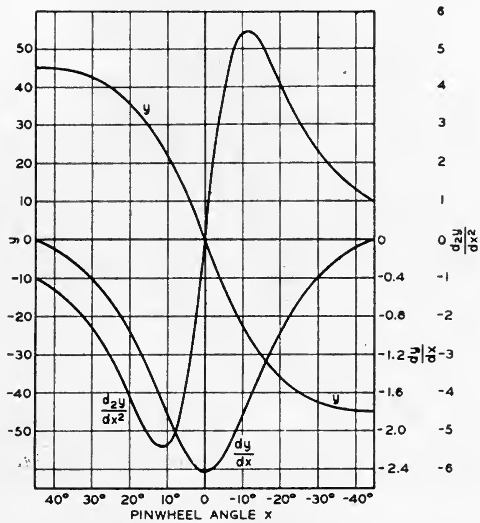


FIG. 7. Displacement, velocity, and acceleration of star-wheel.

During this part of the throw, the changes in y depend on the motion of P_2, and the effect on y of a small movement $-Adx$ of P_2 depends on the components of $-Adx$ parallel and perpendicular to B. We must therefore figure out the angle between the direction of motion of P_2 and follower surface B, and this is the same as that between A and R, indicated as W in Fig. 9, in which it is seen that

$$W = x + y + \theta - 90 \text{ degrees} \tag{7}$$

If x decreases by $-dx$, P_2 moves $-Adx \cos W$ parallel to B and $-Adx \sin W$ perpendicular to B, as illustrated in Fig. 10A. Movement of P_2 parallel to B (a right angle being maintained at T, and R being constant) simply lengthens B without affecting y. If P_2 moves downward by $-Adx \sin W$, it pulls T down, by the same amount, or decreases y by $\frac{-Adx \sin W}{B}$, whence

$$\frac{dy}{dx} = \frac{A}{B} \sin W \tag{8}$$

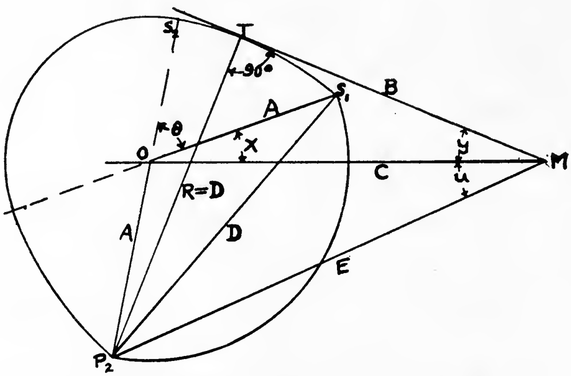


FIG. 8. While follower B rests on arc S_1S_2, finding y for a given x calls for solution of 2 triangles, first MOP_2 and then MTP_2.

Then, $\sin W$ and B being both functions of x,

$$\frac{d_2y}{dx^2} = A\left(\frac{B\frac{d}{dx}\sin W - \sin W\frac{dB}{dx}}{B^2}\right) \tag{9}$$

In this we must substitute the values of $\frac{d}{dx}\sin W$ and $\frac{dB}{dx}$

$$\frac{d}{dx}\sin W = \cos W\frac{dW}{dx}, \text{ and from (7) and (8),}$$

$$\frac{dW}{dx} = 1 + \frac{dy}{dx} = 1 + \frac{A}{B}\sin W, \text{ whence}$$

$$\frac{d}{dx}\sin W = \cos W\left(1 + \frac{A}{B}\sin W\right) \tag{10}$$

Both components of $-Adx$ affect B. As just stated $-Adx \cos W$ lengthens B by the same amount, while $-Adx \sin W$, in changing y, also changes the direction of R by the same angle, namely, $-dy$ (since R and B are perpendicular to each other). As shown in Fig. 10B, this lengthens B by $R(-dy)$ which from Eq (8) is $-R\left(\frac{A}{B} \sin W\, dx\right)$. Then, adding the effects on B of the 2 components of $-Adx$,

$$dB = -Adx \cos W - R\frac{A}{B} \sin W\, dx$$

$$\frac{dB}{dx} = -A \cos W - \frac{RA}{B} \sin W \qquad (11)$$

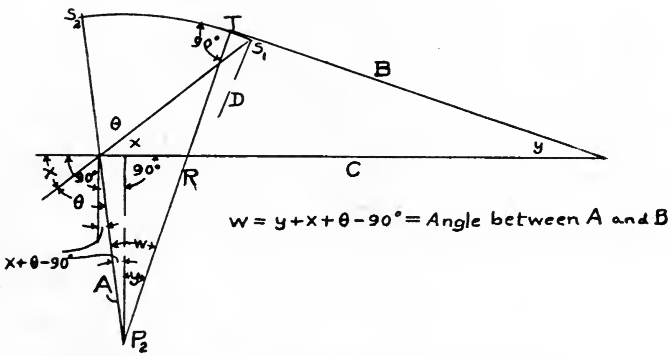


FIG. 9. Establishment of angle between A and R.

Substituting Eqs (10) and (11) in (9)

$$\frac{d_2y}{dx^2} = \frac{A}{B^2}\left[B \cos W\left(1 + \frac{A}{B} \sin W\right) - \sin W\left(- A \cos W - \frac{RA}{B} \sin W\right)\right]$$

$$= \frac{A}{B} \cos W + \frac{A}{B} \cos W \frac{A}{B} \sin W + \frac{A^2}{B^2} \sin W \cos W + \frac{RA^2}{B^3} \sin^2 W$$

$$= \frac{A}{B} \cos W + 2\left(\frac{A}{B} \cos W\right)\left(\frac{A}{B} \sin W\right) + \frac{R}{B}\left(\frac{A}{B} \sin W\right)^2 \qquad (12)$$

The above expression does not appear to be written in its simplest form, but for purposes of calculation, it is believed to be in the most convenient form.

Fig. 11 shows the calculated displacement, velocity, and acceleration curves for a flat follower held against a constant-diameter cam, with center distance C equal to $2A$. The 2 parts of the curve are not identical, as was to be expected with different formulas, but the difference is not large.

The method of calculating the second part of the curve (Eqs (8) and (12)) may be applied to the problem of making allowance for the addendum r at the corner, for it covers the general case of a flat follower passing through a pivot point M, and maintained tangent to a circular arc whose center moves in a circle about the cam shaft axis O.

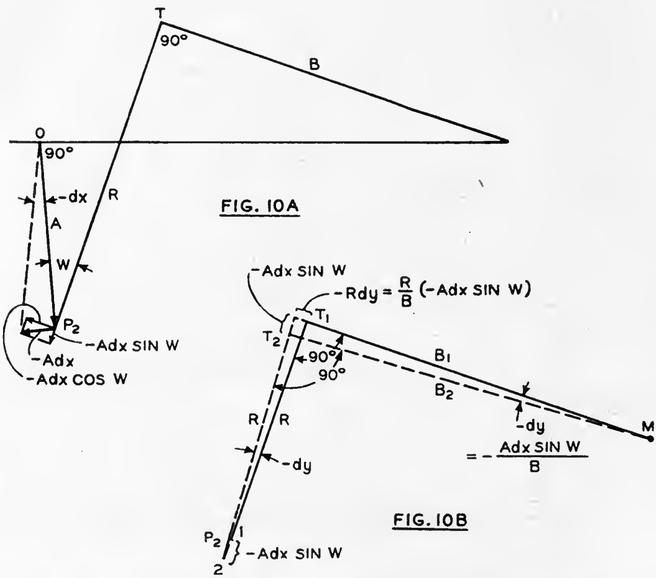


FIG. 10A. Components of $-Adx$, parallel and perpendicular to B.
FIG. 10B. Effect on B and y of movement of P_2 in direction of perpendicular to B.

The expression for the angle W will have to be correctly formulated in each case.

If the surface of the follower is not radial with respect to its pivot the formulas (8) and (12) may be used by choosing an appropriate new value for R. This may be illustrated for the common case in which the follower is in the form of an open rectangle whose mid-line MN, Fig. 12, passes through the pivot axis. The total diameter of the cam is $D + 2r$ and the 2 follower surfaces are this distance apart. During the first part of the downward movement, the surface F_1 is tangent to the arc S_3S_1, which is r above P_1. At the same time the mid-line MN, which is $\frac{D}{2} + r$ below F_1, is $\frac{D}{2}$ below P_1 and therefore tangent to a circular arc S_4S_6, with P_1 as the center and $\frac{D}{2}$ as its radius. When the point of tangency of F_1 passes to the arc S_1S_2, motion is determined by the position of P_2. F_1 is $D + r$ above P_2 measured perpendicular to F_1. At the same time the mid-line MN is $\frac{D}{2}$ above P_2 and therefore

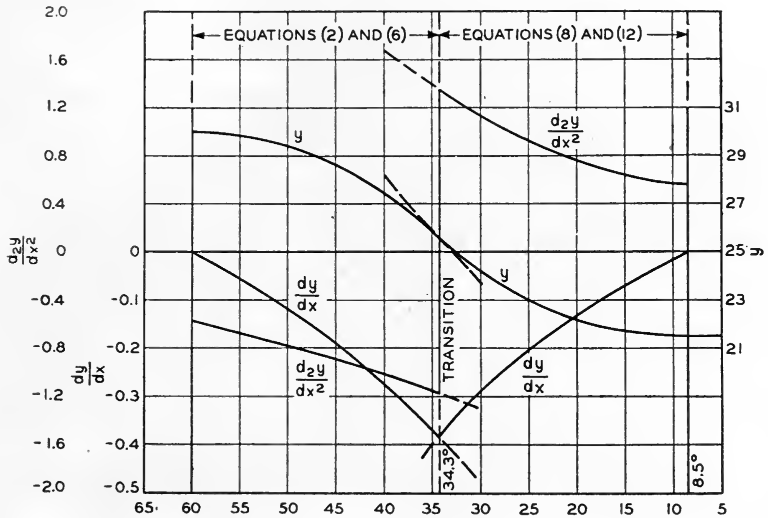


FIG. 11. Motion characteristics of cam of Fig. 2, with pivoted follower, $C = 2A$.

tangent to a circular arc S_6S_5 having its center at P_2 and a radius $\frac{D}{2}$.

In the case of the follower whose surfaces F_1 and F_2 are parallel and equally distant from the radial line MN, the 2 parts of the movement are symmetrical, and therefore only one part needs to be calculated.

Some comments on the several curves of acceleration may be in order: If a mass is to be moved through a given distance in a specified time, this can be accomplished with the smallest maximum applied forces if the acceleration is maintained constant for half the time or distance, and then an equal constant retarding force applied until the mass is brought to rest. The curve of displacement versus time consists of 2 parabolic segments. To accomplish the same travel, sinusoidal movement would require 11 per cent longer time with the same maximum acceleration. Reference to Fig. 3 will show that for the case considered, acceleration and retardation are maintained throughout their periods of action between maximum and 0.87 of the same, thus approximating very closely the constant acceleration condition.

Figs. 11 and 13 show that with pivoted followers, the acceleration is not maximum at the start but increases (in the case illustrated) to a maximum of about twice the initial value.

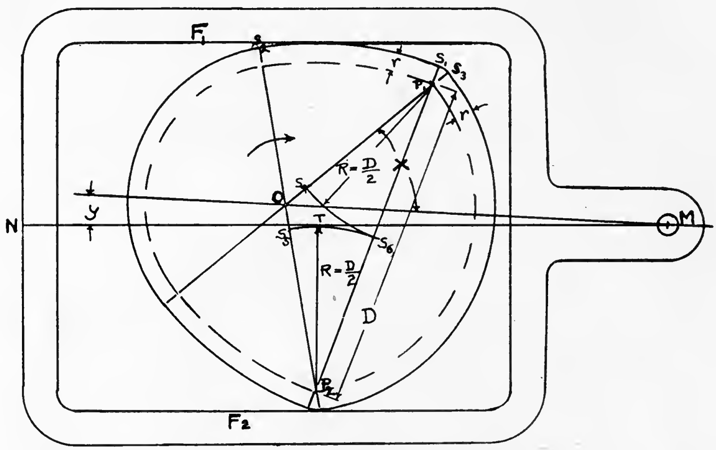


FIG. 12. Cam with open rectangle follower, an example of the more general problem of a follower with a flat surface which is not radial with respect to the pivot point M.

Figs. 11 and 13 were calculated for cases of unusually short relative distance between shaft and pivot. A very large distance would give characteristics approximating those of Fig. 3 in which the acceleration falls off slightly from the initial value. With medium pivot distances the conditions of constant acceleration and retardation may be approximated even more closely than Fig. 3.

From the standpoint of mechanical wear, constant acceleration or an approximation thereto is desirable, but in other respects a lowered initial value of acceleration and final value of retardation may have some advantages, for this means that the film gets under way more slowly and comes to rest more gradually, and these in turn mean reduced travel ghost for the same over-all pull-down time and shutter blade width. The Geneva movement, see Fig. 7, is a rather extreme example of maximum acceleration near the middle of the stroke, the maximum acceleration being about 5.5 times the initial, and it is known to be quite common practice to permit considerable light on the screen at the instant that the pin enters and leaves the slot.

Ordinarily dependence is placed on gate friction to apply the necessary retarding force to the film itself, but assuming that the film is sufficiently supported between the gate and the sprocket so that it will not buckle, it will be recognized that some of the retarding force may be provided by the sprocket teeth, provided this does not occur too near the end of the movement. In order to afford accurate registration or freedom from picture jump, the front face of the tooth must

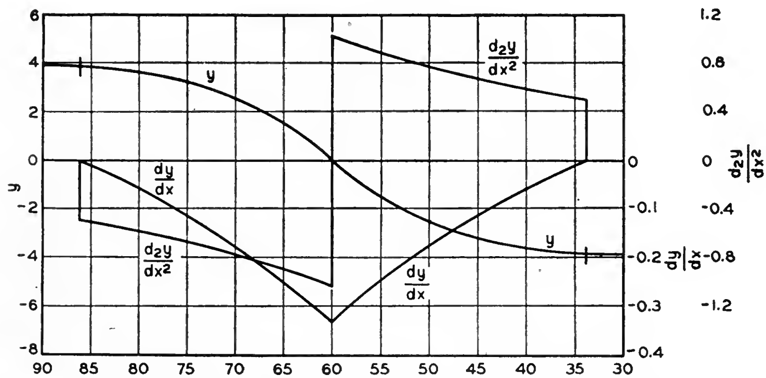


FIG. 13. Motion characteristics of cam and follower of Fig. 12.

be in contact with the front edge of the perforation at the end of the pull-down. If at any time it loses contact (as it must do if the sprocket helps to retard the film) it must reestablish contact before the end. Gate friction must therefore exceed film retardation force, throughout a sufficient distance at the end, for the sprocket to catch up, or in other words, for a distance somewhat greater than the clearance or backlash between tooth and perforation. In the case of the Geneva movement, it seems reasonable to believe that at the time of maximum retardation, the back of the tooth may engage the back of the perforation and thus help retard the film, but the sprocket still has room to catch up to the film and end the pull-down with forward tension on the film, which is necessary for controlled final position.

TECHNICAL NEWS

The items appearing in this section were submitted July 12, 1945, by members of the Technical News Committee, who welcome and will consider items of current technical interest from any member of the Society.

Additional information concerning these items, or the equipment and processes discussed, may be obtained by communicating with the General Office of the Society, Hotel Pennsylvania, New York 1, N. Y.

PROCESS PHOTOGRAPHY

The Optical Department of RKO Radio Pictures, which is under the supervision of Vernon Walker and Linwood Dunn, has been engaged in duping several reels of the old 28-mm film to 35-mm for release in the *Flicker Flashback* series of RKO shorts. The film was chosen from a library of over 100 reels owned by Walter Green. Twenty-eight millimeter film was the early standard size for nontheatrical use on noninflammable stock. This film was popular shortly after World War I and was finally supplanted by 16 mm.

Among the films duped are Chaplin's *Adventurer* (1916), D. W. Griffith's 2-reeler *The Battle of Elderbush Gulch* with Lillian Gish (1913), and *Romeo and Juliet* with Florence Turner (1910).

A 28-mm Peerless projector was adapted to the optical printer and the results were excellent. The 28-mm film is in good condition probably owing to the fact that it was never subjected to the wear of theatrical use.

TELEVISION

The framework for commercial post-war television has been very nearly completed by the Federal Communications Commission in their report of June 27, 1945, and their current correlative activities. The final allocation is as follows:

Freq. Band (Mc)	Proposed Allocation
42–44	Nongovernment Fixed and Mobile
44–50	Television—Channel No. 1
50–54	Amateur
54–60	Television—Channel No. 2

60–66	Television—Channel No. 3
66–72	Television—Channel No. 4
72–76	Nongovernment Fixed and Mobile
76–82	Television—Channel No. 5
82–88	Television—Channel No. 6
88–92	Noncommercial Education FM
92–106	FM
106–108	Facsimile

An informal technical conference was held by the FCC on July 13, 1945, to pass upon the standards formulated by the Radio Technical Planning Board over the past year or more. With the Radio Manufacturers Association Engineering Committee on television fairly well along in formulating the industry practices under the RTPB standards, the way is clear for detailed engineering design of both broadcasting and receiver equipment.

Since numerous television broadcasters are already in operation in the large cities, the responsibility for rapid progress in commercial television lies with the television receiver manufacturer. As soon as he can produce in quantity and sell good television merchandise, the advertiser will enter the field and the perennial dilemma of who shall come first will be solved. Receiver manufacturers will be wise to stay with JAN quality components if they wish to do the best for the public, the art, and themselves.

In the Hollywood area an important development has been the announcement of the Southern California Edison Company that they intend to convert their 50-cycle electric power service to 60 cycles. This will bring the vast hinterlands of Southern California on the same power system as the cities of greater Los Angeles, and obviously simplify television broadcasting and receiver technology.

SOCIETY ANNOUNCEMENTS

PACIFIC COAST SECTION MEETING

An interesting discussion of foreign language versions of American motion pictures was conducted at the meeting of the Pacific Coast Section of the Society on June 26. Five speakers from major Hollywood studios took part in the program under the title "Symposium on Foreign Language Versions." Those speaking and their subjects were: Luigi Luraschi, Paramount, discussed "The Foreign Market—Past, Present and Future"; John Bodnar, Twentieth Century-Fox, spoke on "Methods of Foreign Release of American Pictures"; Jack Cutting, Walt Disney Studios, spoke on "Showmanship in Foreign Release of American Pictures"; James Stewart, RKO, discussed "Preparation for Foreign Dubbing"; and John Livadary, Columbia, spoke on "Recording Techniques for Foreign Versions."

A large audience participated enthusiastically in the discussion period following presentation of the papers and exhibition of sample reels of foreign language versions. Because of the interest in this general subject, the speakers have been requested to prepare their material for publication in the JOURNAL.

The meeting, which was held in the ERPI Review Room, was preceded by a dinner at the Hollywood Athletic Club where the speakers were guests of local Section officers.

EMPLOYMENT SERVICE

POSITIONS OPEN

Position open for man or woman with experience in optical instrument design. Position also open for man or woman with experience in lens design or computing. Write for interview. Binswanger and Company, Optics Division, 645 Union Ave., Memphis, Tenn.

Physicist with special training in optics for research on utilization of carbon arcs particularly in projection systems. Apply to Research Laboratory, National Carbon Co., Inc., P. O. Box 6087, Cleveland 1, Ohio.

Designer and engineer experienced in optics, lighting, and microphotography, capable of designing microfilm reading equipment and products related to microfilm industry. Reply to Microstat Corporation, 18 West 48th St., New York 19, N.Y.

Design engineer, experienced in mechanics and optics of motion picture cameras, projectors, and film scanning. Give details. Reply to Mr. John H. Martin, Columbia Broadcasting System, Inc., 485 Madison Ave., New York 22, N.Y.

POSITIONS WANTED

Sound recording engineer, 16- or 35-mm equipment, studio or location work, single or double system. Free to travel. For details write J. J. K., 354 Ninth Ave., New York 1, N.Y.

Honorably discharged veteran with 15 years' experience in all phases of motion picture production, including film editing, directing, producing. For details write F. A., 30-71 34th St., Long Island City 3, N.Y. Telephone AStoria 8-0714.

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

We are grieved to announce the death of Charles E. Shultz, Active member of the Society, on August 8, 1945, at Willever Lake, New Jersey.

MEMBERS OF THE SOCIETY LOST IN THE SERVICE OF THEIR COUNTRY

FRANKLIN C. GILBERT

ISRAEL H. TILLES

MORGAN L. HOBART

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 **SEPTEMBER, 1945** **No. 3**

CONTENTS

Indexes to the semi-annual volumes of the Journal are published in the June and December issues. The contents are also indexed in the *Industrial Arts Index* available in public libraries.

JOURNAL

OF THE

SOCIETY of MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA • NEW YORK 1, N. Y. • TEL. PENN. 6 0620

Subscription to nonmembers, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscription or single copies of 15 per cent is allowed to accredited agencies. Order from the Society at address above.
Published monthly at Easton, Pa., by the Society of Motion Picture Engineers, Inc.
Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, Hotel Pennsylvania, New York 1, N. Y.
Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 SEPTEMBER, 1945 No. 3

SOME PRACTICAL ASPECTS OF THE INTERMODULATION TEST*

E. MESCHTER**

Summary.—*The intermodulation test provides a measure of the distortion introduced by a sound system through its failure to reproduce two or more frequencies without interaction between them. The principles underlying the measurement of intermodulation are described, and procedures for testing both negative and positive films are outlined. Results representative of both standard and experimental stocks and processing are given.*

The interpretation of various families of intermodulation versus print density curves in terms of film characteristics is discussed. Test modifications required by the introduction of noise reduction bias and results obtained under such conditions are described. Application of the intermodulation test to 16-mm films is shown to require no fundamental change in the test procedure.

The intermodulation method of investigating distortion on variable-density sound tracks, as described by Frayne and Scoville,[1] has been of great value in controlling and improving sound quality. Limited at first to a comparatively small number of users, interest in the method has been constantly increasing. This trend has received added impetus from requests by the Armed Forces, directed to the American Standards Association, for standards of quality for 16-mm prints.

In view of this wider interest it appears desirable to describe some of the simple and practical features of procedures and conclusions which have been encountered during the past few years in using the method for the study of emulsions in the Research Division of the du Pont Photo Products Department.

* Presented Dec. 13, 1944, at a meeting of the Atlantic Coast Section of the Society.

** Research Division, Photo Products Department, E. I. du Pont de Nemours and Co., Parlin, N. J.

The theory and underlying principles of this intermodulation measurement, as well as the equipment itself and its applications to the study of film processing, have been described by Frayne and Scoville[1] and also by Hilliard.[2] No detailed account of the theory

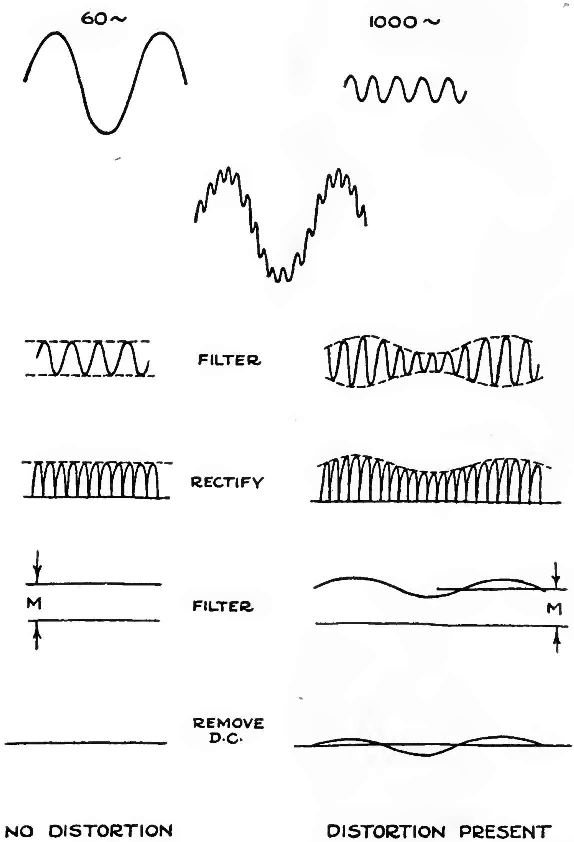


FIG. 1. Schematic representation of the intermodulation test.

will therefore be attempted here, but a brief résumé is included for the sake of convenience.

Fig. 1 shows the 2 signals which are usually recorded on the negative: one of 60 cycles, and one of 1000 cycles whose amplitude is 25 per cent that of the 60-cycle signal. These two are mixed, and recorded so that the combined signal is 2 db below valve clash. Low frequencies other than 60 cycles are sometimes employed for special work, and 400 cycles has been used as the high frequency. These changes, however, require modification of the analyzer circuit and so are not easily introduced.

The negative is developed and printed, and the print is run through a reproducer and preamplifier, to which the intermodulation analyzer is attached. All of the steps from here on, with the exception of the manual adjustment of the input level to the analyzer, are performed automatically by the analyzer.

The complex input wave is first put through a band pass filter which removes the 60-cycle component, leaving a 1000-cycle signal. If no distortion has been introduced, the amplitude of the 1000-cycle signal will be constant as at the left of Fig. 1. If nonlinearity is present, the amplitude of the 1000-cycle wave will vary periodically as at the right; that is, the 1000-cycle signal has been intermodulated by the 60 cycles. This variation may be either 60 or 120 cycles, depending on whether the distortion is introduced at one or both ends of the density swing.

The 1000-cycle signal is then amplified and rectified. After filtering out the 1000-cycle ripple, there remains a d-c signal whose average magnitude is indicated as M; this may or may not have a 60- or 120-cycle signal superimposed on it, depending on the presence or absence of distortion. M is a measure of the amplitude of the original 1000-cycle signal; manual adjustment brings it always to a constant level, which may be designated as 100 per cent.

The d-c signal, with or without the fluctuation, is put through a transformer and again amplified. The steady signal on the left gives zero result through the transformer and zero distortion is indicated. The alternating component of the signal on the right comes out as indicated below. The average value* of this signal is a measure of the distortion present; after rectification and smoothing it is read by a meter calibrated as per cent intermodulation referred to M above as 100 per cent. These are the bare essentials of the measuring system as shown by one measurement.

The original signals do not need to be derived from any extraordinarily high-quality sources. Commercial 60 cycles is satisfactory for the low-frequency component, and a small beat-frequency oscillator

---

* Average values are usually used, although peak and rms measurements have sometimes been employed.

can be used to obtain the 1000 cycles. Limits of ±3 per cent in frequency and a total harmonic content of less than 5 per cent should be adequate for all but the highest precision work.

Care should be taken in mixing that the sources do not react with each other to give something other than the desired 4 to 1 amplitude ratio; a cathode-ray oscillograph is a very convenient device for checking the wave form of the combined signal.

Sections 12 to 15 ft in length give ample time for each measurement. A few inches of unmodulated and unbiased track should be recorded at the start or end of each section for density measurement.

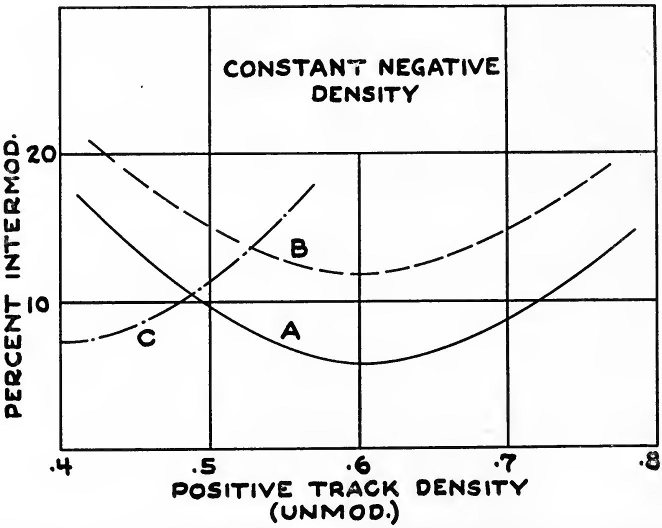


FIG. 2. Intermodulation curves showing (*A*) good intermodulation, (*B*) poor intermodulation, and (*C*) displaced minimum.

After development each negative section is printed at at least four and preferably more printer points, to insure sufficient data to draw a good curve. The densities of the unmodulated sections on the final print should bracket the usual operating region of 0.55 to 0.60. The results are usually represented graphically as shown in Fig. 2, in which the per cent intermodulation for each section has been plotted against the unmodulated positive track density corresponding to that section.

Curve *A* represents a very good result; minimum distortion is a low value at the desired density of 0.6. Curve *B* is not as good; distortion does not reach as low a value as *A*, but the minimum occurs at the proper print density. This curve does not represent bad sound, but merely not quite the best. Curve *C* is a definitely undesirable result; to obtain low distortion it has been necessary to print at an unmodulated track density of about 0.4—much too light. This distortion can arise when a negative intended for UV printing is printed with white light; the effective contrast of the positive is then too high and it is necessary to work down on the toe of the positive characteristic curve to obtain low intermodulation.

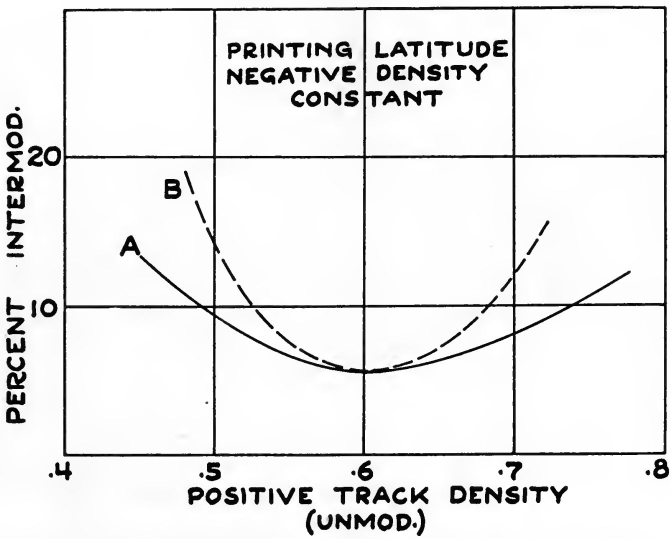


FIG. 3. Intermodulation curves resulting from use of different print stocks; *A* shows greater latitude than *B*.

These curve shapes are typical of intermodulation results in that each possesses a minimum, which serves to indicate the one best print density for the particular combination of stocks and processing under consideration. Intermodulation may actually rise to very high values; those in the illustration have been cut off at about 20 per cent merely for convenience.

In Fig. 3 are shown some possible results when the same negative is printed on 2 different positive stocks, as before at a variety of positive track densities. At the optimum track density, 0.6, no difference between the 2 stocks is discernible; however, for departures from this optimum point the distortion of *B* rises much more rapidly than that of *A*. The printing latitude of *A* is therefore greater than that of *B*, and *A* is preferable. The explanation of this effect is fairly complicated, tracing back to the curvature of the positive characteristic curve over the range of operating densities.

Fig. 4 shows the effect of varying the recorder lamp current and hence the negative track density of a standard type of VD negative When all these negatives are printed on the same standard positive material, the print density required for minimum distortion in each case is approximately 0.6, regardless of moderate variations in nega-

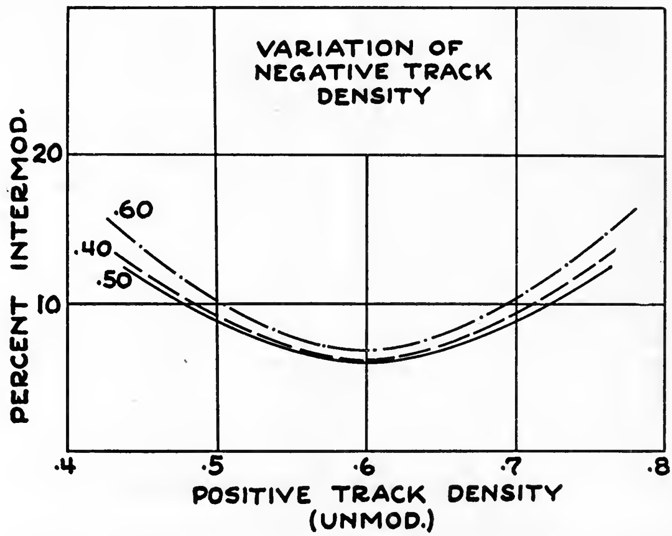


FIG. 4. Intermodulation results from a negative stock showing normal sensitometric curve shape.

tive density. In making prints, therefore, it is sufficient to work to a constant positive track density to insure best results; it is not necessary to make any allowance for negative density. A negative whose characteristic curve is essentially a straight line over a sufficient range of density gives this result, although departures can always be expected if the recording range is sufficiently great.

Such a situation does not always exist, as is shown in Fig. 5. In this case track density on an experimental negative has been varied by changing recorder lamp current and the prints have been made on the same standard positive stock mentioned above. Here the positive track density at which minimum intermodulation occurs definitely does depend on the density of the negative; heavier negatives must be printed lighter to obtain best results, while lighter negative tracks give lower distortion with darker prints. This situation has interesting possibilities. It should be possible to use a negative stock of this type as a sort of self-timing negative. If all takes are run through at a fixed printer point, the tendency will be to correct the print density automatically toward lower final distortion. The disadvantage is, of course, that the variable print density will give a variable output level.

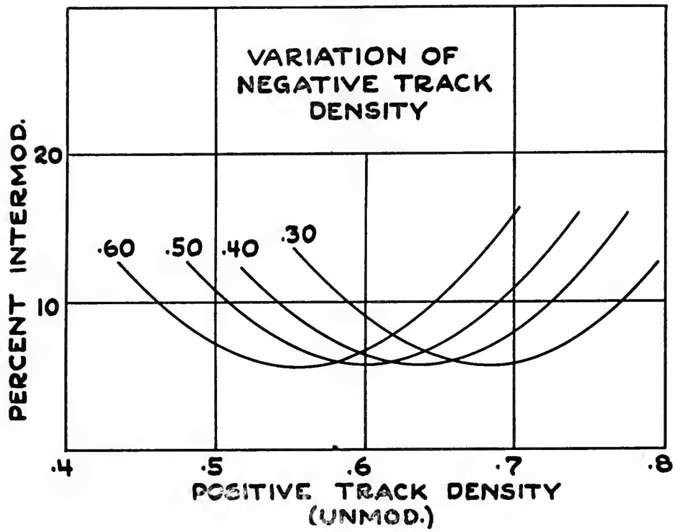


FIG. 5. Intermodulation results from a negative stock having unusual curvature in its sensitometric characteristic.

The type of negative characteristic curve which produces this result is shown in Fig. 6. This long sweeping curve, which is practically all toe and with no straight line portion, causes the density swing from A to A' to be quite different from that of B to B' although the change in log E produced by the light valve is the same in each case. Heavier exposures use a section of the negative characteristic curve where the slope is greater; in order to obtain minimum distortion it is necessary to print these farther down on the toe of the positive characteristic where the slope is lower.

The preceding discussion is based upon a signal recorded at 2 db below valve clash, nearly full modulation. When noise-reduction systems are employed additional complications are introduced and additional data are required to insure optimum operation. To obtain these data a second section is recorded at 12 db below clash with 10 db of noise reduction, and the intermodulation is measured and plotted in the same way as in the previously described tests. Fig. 7 shows the −2 db and −12 db curves, in which intermodulation has been plotted as a function of the unmodulated and unbiased track density. The combination of curves *A* and *C* represents a satisfactory situation; low distortion at both levels is obtained for an unmodulated and unbiased track density of 0.6.

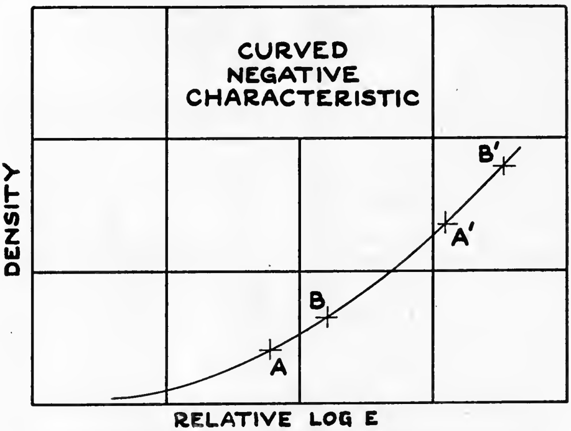


FIG. 6. Sensitometric curve typical of negative stocks yielding intermodulation results shown in Fig. 5.

Curve *B* results when the recording stock has insufficient toe. When the noise reduction starts to operate and the density of the negative decreases (to give a darker print and reduce noise) the contrast of the negative remains high. It is then necessary to make a lighter than normal positive print, to operate further down on the positive toe where the slope is lower. Curves *B* and *C* demand that the unbiased and unmodulated track density shall be 0.4 and 0.6 simultaneously to give minimum distortion for both loud and soft sounds. In the face of this obvious impossibility it must be concluded that the negative stock under consideration (or its processing) is unsatisfactory.

The application of the intermodulation test to checking of 16-mm films and processing is not difficult. The maximum frequency employed is 1000 cycles, so it is not necessary to change this on going from 35-mm to 16-mm conditions, and no change in the signal generating apparatus is required.

As in the case of 35 mm, it is desirable to check the amplifier of the reproducer for possible intermodulation which may be introduced by the equipment itself. This may be done by introducing the signals directly into the amplifier and noting the reading of the intermodulation analyzer.

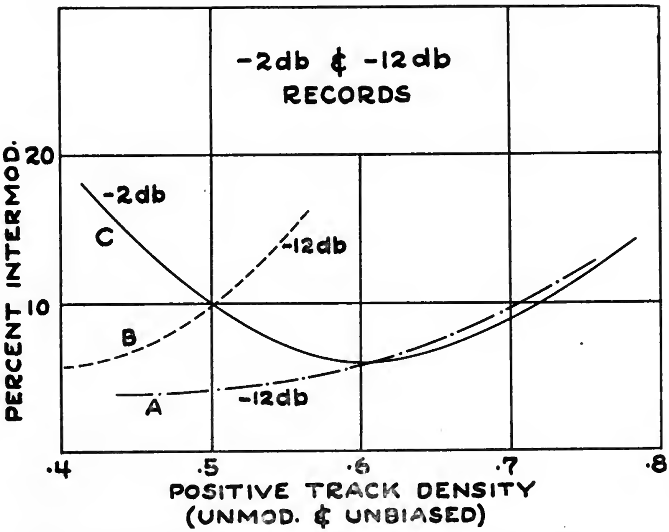


FIG. 7. Intermodulation curves showing performance in recording systems using noise reduction. Combination *A* and *C* is satisfactory while *B* and *C* is unsatisfactory.

The frequency response characteristic for 16-mm amplifiers given in the American War Standard for Service Model 16-Mm Projectors permits a drop of 9 db at 50 cycles under the output at 1000 cycles. This does not interfere with the operation of the test, however, since the first step in the analyzer is the filtering out of the 60-cycle component. The signal level is adjusted by observation of the 1000-cycle component, so the possible lower response at the lower frequency does not in itself introduce any error into the measurement.

For an over-all check of the reproducing system, including the photocell and its coupling circuit, it is necessary to employ a test film; specifications for such a test film have not been worked out by the American Standards Association at this writing.

In closing, it should be emphasized that the intermodulation test in itself cannot be used to the exclusion of listening tests as an indication of sound quality. Each furnishes its own particular type of information, and intelligent use of both in combination should lead to the best possible control of stocks and processing.

REFERENCES

[1] FRAYNE, J. G., AND SCOVILLE, R. R.: "Analysis and Measurement of Distortion in Variable-Density Recording," *J. Soc. Mot. Pict. Eng.*, **XXXII,** 6 (June, 1939), p. 648.

[2] HILLIARD, J. K.: "Distortion Tests by the Intermodulation Method," *Proc. I. R. E.*, **29,** 12 (Dec., 1941), p. 614.

8000 PICTURES PER SECOND *

HOWARD J. SMITH**

Summary.—*A brief outline is given of the development and design of the Western Electric Fastax high-speed motion picture camera. This camera takes up to 8000 pictures per sec on 8-mm film.*

The engineers and scientists of today have a number of methods at their disposal as aids in the study of high-speed phenomena that are beyond the range of perception of the human eye. These methods include the use of optical lever, shadowgraph, oscillograph, oscilloscope, stroboscope, spark or flash photography, and the high-speed motion picture. All of these methods are being used today in analyzing high-speed motion pertaining to the war effort.

The high-speed motion picture camera is the most versatile of these devices for studying mechanical motions and other high-speed phenomena, in that it may be used independently, or in conjunction with some of the above-mentioned devices. It can record phenomena regardless of whether the motion is repetitive or nonrepetitive on a film that can be viewed either frame by frame for measurement, or as a motion picture to portray the action in slow motion. Such pictures are a complete and direct representation of the action as compared to the indirect or partial indices of motion obtained from such instruments as optical levers, oscilloscopes, *etc.* The action, when photographed at a high rate of speed and projected at a slow rate of speed, will be retarded or "magnified" by the ratio of these 2 speeds. For example, the newly developed Fastax camera will take pictures up to 8000 pictures per sec. When these pictures are projected at a rate of 16 pictures per sec, a time "magnification" of 500 to one can be obtained.

In order to take motion pictures at this ultra-high speed, the film must be propelled through the camera at a velocity of 100 ft per sec, or approximately 70 mph.

---

* Presented Oct. 18, 1944, at the Technical Conference in New York.

** Member Technical Staff, Bell Telephone Laboratories, Inc., New York.

The conventional start-stop mechanisms of the intermittent-type motion picture cameras have been made to operate as high as 400 pictures per sec[1] although it is unusual for them to run much above 128 pictures per sec. It would be extremely difficult to build a reciprocating mechanism to operate reliably at speeds in the order of 8000 cycles per sec, as would be required in the camera under discussion, and even if a suitable intermittent mechanism could be devised, it is highly doubtful whether the film has adequate strength to resist the forces involved.

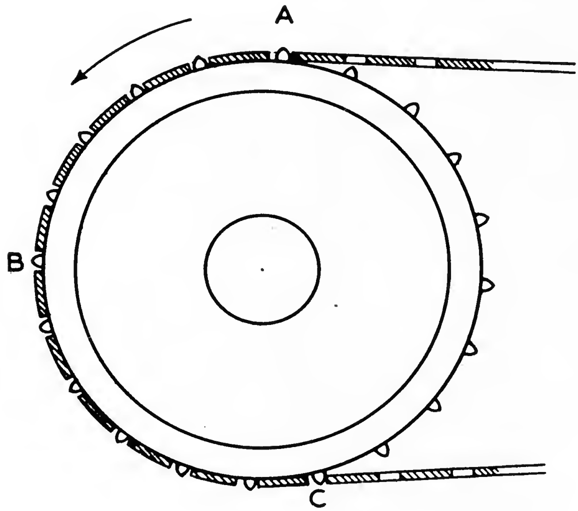


FIG. 1.

However, if the film is propelled continuously in a straight line and at a constant speed of acceleration, considerably higher velocities can be obtained before the tensile strength of the film base becomes a limiting factor. In order to be able to project this film in a standard projector there must be some control exercised to hold the film in the image plane and to hold the picture frame in synchronism with the perforations. The latter condition is easily obtained by the use of a sprocket in contact with the film and located so as to introduce the least amount of strain on the continuously moving film.

An aperture plate or shoe could be used to hold the film in the image plane, but it is difficult to avoid the danger of too much friction in an effort to guide the film at these high speeds and still prevent weaving and "breathing" at the image plane.

The film control in the Fastax cameras is very simple and yet highly efficient. The film path has been arranged so as to permit the sprocket holes to engage at least 10 pairs of sprocket teeth at all times as the film travels around the sprocket from *A* to *C*, Fig. 1. This secures the film firmly on the periphery of the sprocket as it passes the aperture at *B*, minimizing the effect of the centrifugal forces that would tend to throw the film out of the image plane and cause the pictures to go in and out of focus, or "breathe."

The sprocket is coupled directly to the driving motor and is used to propel the film through the camera by its 2 rows of specially designed

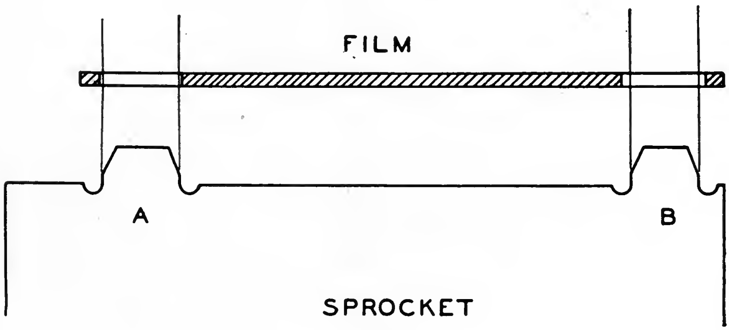


FIG. 2.

and accurately cut teeth. The lateral weave of the film is practically eliminated by having the width of one row of teeth (*A*) on the sprocket almost the width of the film perforations, Fig. 2. These features assure uniform travel of the film at the high speeds of operation involved, but the means used make it necessary for the camera to employ accurately perforated film that is within 0.5 per cent of full pitch.

In addition to smooth film movement at high speed, it is necessary to provide suitable optical compensation to allow the image to follow the movement of the film during the exposure period for each frame.

There are several methods of optical compensation that have been used by designers in the past. One method is the use of a series of matched lenses[2, 3, 4] of high aperture located around the periphery of a large wheel which rotates in front of the film. The lens wheel is driven at a rate of speed equal to the film as it passes the picture aperture. In this manner, one exposure is made through each lens as it moves downward at the same speed as the film; causing the image to remain stationary with relation to the film. If the lenses travel in an arc, there will be some transverse displacement of the image; however, there have been several methods devised to overcome this.[5] There still remain difficult and critical adjustments of each lens and also the problem of securing uniformly matched lenses in quantities.

Another method of optical compensation provides for the downward motion of the image by reflections from mirrors.[6, 7, 8] A revolving drum fitted with mirrors rotates behind the lens. As each mirror face comes into position the image from the lens is reflected to the film which is traveling downward at the same rate of speed as the

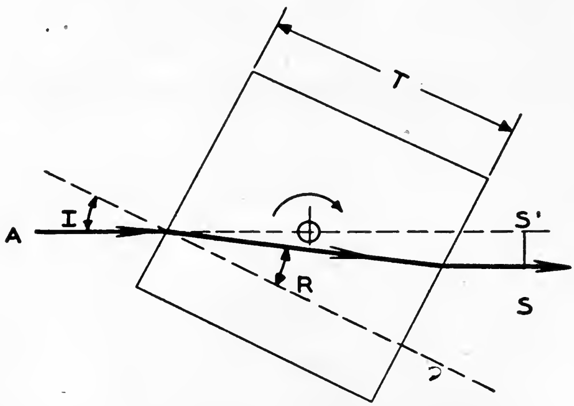


FIG. 3.

reflected image, and one frame is exposed from each mirror face. The adjustment of these mirrors is very critical and the quality of the reflecting medium and the accuracy of the surfaces involved must be very carefully controlled. This method requires the use of long focus lenses, as the distance from the rear element of the lens to the mirrors and then to the film is considerable.

A third and simpler method is the use of a rotating optical compensating prism interposed between the lens and the film plane. This method has been used successfully in several other high-speed motion picture cameras.[9–14] The use of rotating parallel plane glass blocks has been discussed in previous articles,[5, 15, 16] but these generally apply to the rotating prism for use in continuous projectors where the speed of rotation is not high, and where large-size prisms having many faces are used.

Increasing the number of prism faces reduces the amount of the angular tilt of each face as it rotates past the aperture, thereby improving the definition of the refracted image. Unfortunately, increasing the number of faces of the glass polygon and still maintaining the same vertical dimension of the faces calls for increased diameters. For example, a 4-sided prism having faces with the vertical dimen-

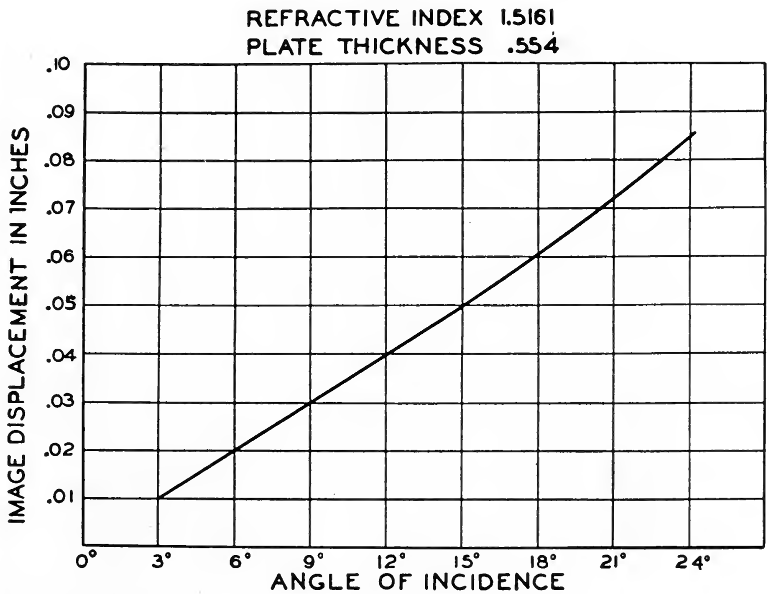


Fig. 4.

sion approximately 0.265 in. high and a diameter of 0.554 in. would have its diameter increased to 1.10 in. for 8 faces, and 1.65 in. for 12 faces, *etc.* As the diameter of the glass block increases, it becomes more difficult to secure suitable glass having the proper optical qualities required for making the prism. The difficulties of maintaining accurately the angular and linear dimensions of the prism are increased. The prism becomes bulkier with the increased mass, and in turn increases the danger of rupture generated by the centrifugal forces involved at high speeds of rotation.

The advantages obtained by the increased number of faces of the prism were utilized in the camera under discussion by designing a prism having 4 pairs of polished faces forming an octagon. The diameter was held to a minimum by reducing the vertical dimension

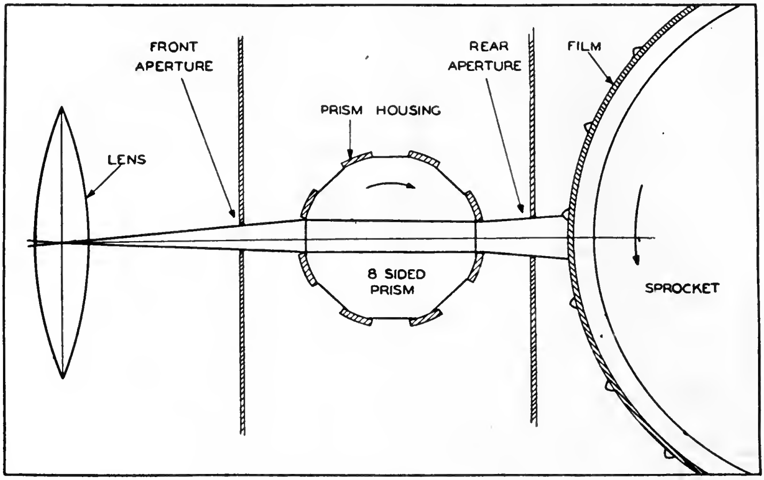
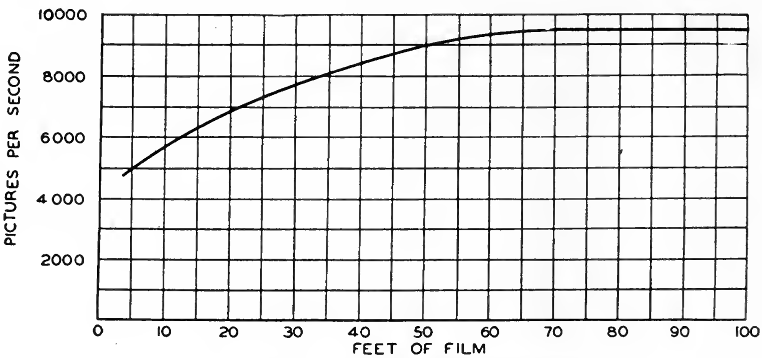


FIG. 5.

of the faces to approximately 0.125 in., which is suitable for 8-mm pictures. The angular dimensions are held to very close tolerances to assure uniform refraction of the image during rotation of the prism.



SPEED CHARACTERISTICS
AT 130 VOLTS AC

FIG. 6.

The index of refraction, the location of the prism with respect to the sprocket, and the dimensions of the prism are computed to give the correct movement of the image as the film moves continuously past the aperture. Fig. 3 shows a plane parallel glass plate representing any 2 parallel faces of the prism. If a light ray, A, enters the plate at the angle of incidence I, it passes through the plate at the angle of refraction R, and emerges parallel to the angle of incident

FIG. 7. Typical arrangement of lighting units for high-speed photography.

ray, but is displaced by the distance SS'. The deviation of SS' produced by the thickness of the plate T is found by

$$SS' = \frac{T \sin (I - R)}{\cos R}$$

Fig. 4 shows a curve of the displacement SS' at different angles of incidence. This curve is linear up to 15 degrees. Therefore, to obtain uniform displacement of the image the tilting angle should not exceed this amount.

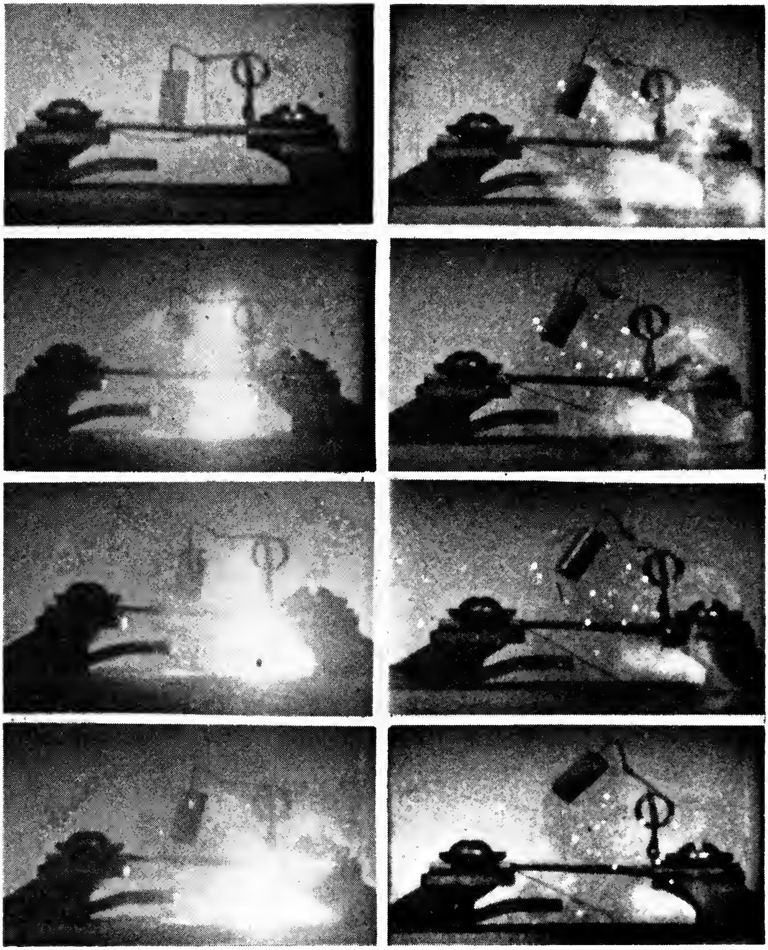


FIG. 8. Frames enlarged from a strip of 8-mm film taken at 8000 pictures per sec at $f/8$, showing the action of a telephone fuse known as the "grasshopper."

The 8-sided prism rotates through 45 degrees for each picture frame on the sprocket. A point on the film moves 0.0375 in. past the aperture during this portion of a rotation. An angle of tilt of $11^1/_2$ degrees will give an image displacement of this amount. The angle of tilt is controlled by a housing which surrounds the prism. This housing has 8 apertures centered on the prism faces. Each aperture cuts off the incident rays at the selected angle of the outgoing face and does not permit the rays to pass through the prism until the incoming prism face has reached a corresponding angle of tilt, as shown in Fig. 5.

The prism housing in conjunction with a front and rear aperture plate acts as a barrel-type shutter. The exposure time is controlled

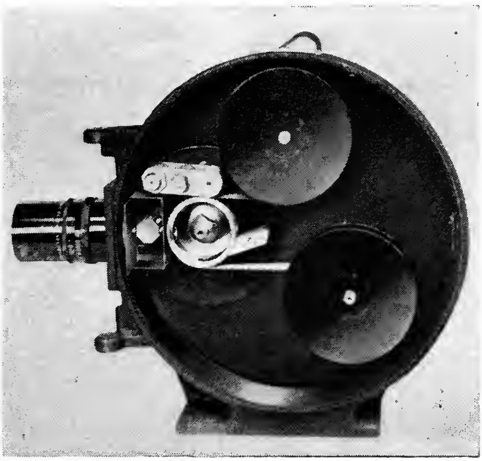


FIG. 9. Fastax camera with door removed showing compensating prism, sprocket, and film path. The open box around the compensating prism contains the front and rear aperture.

by the speed of rotation of the prism housing. If the prism rotates at 60,000 rpm, pictures are taken at the rate of 8000 pictures per sec, and each picture receives an exposure of approximately 33 microseconds. If the prism rotates at 7500 rpm, the taking rate will be 1000 pictures per sec, and each picture will receive an exposure of approximately 350 microseconds.

The interposition of the prism between the lens and the film requires the use of lenses having a back focus of sufficient length to permit focusing the image on the film. The shortest focal length lens that may be used with this camera is 35 mm.

The motive power to drive the camera is supplied by two $^1/_4$-hp, series-wound, universal-type motors having high starting and accelerating torques, and designed for high-speed applications where the load is directly connected and the duty is intermittent. One motor drives the sprocket to which the compensating prism shaft is geared, and the second motor drives the take-up reel. This large amount of power is used so as to accelerate the film to its maximum speed in the shortest possible time. By this means, it is possible to obtain pictures at maximum taking speed on at least 60 per cent of the 100-ft rolls of film used in the camera. The acceleration characteristics of the camera as finally constructed are shown in Fig. 6.

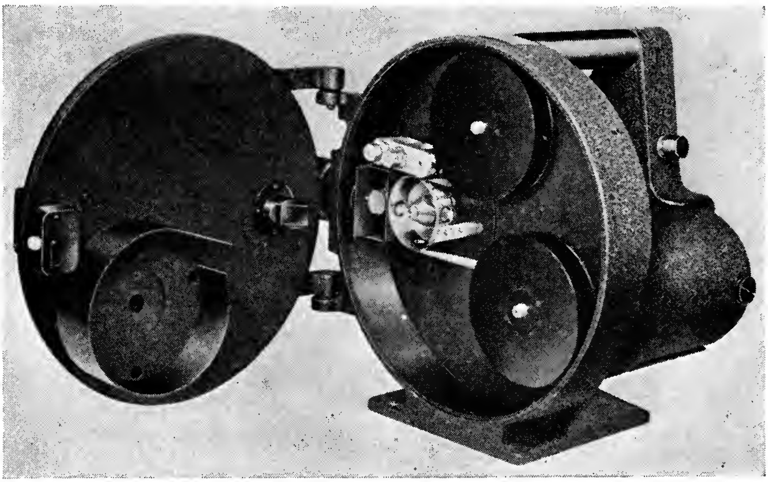


FIG. 10. View with door open shows the film guard for the take-up reel, and the prism for the reflex viewer.

Pictures taken at a rate of 8000 per sec require the highest order of illumination. The most convenient type of lighting units for this purpose are the tungsten filament "sunspots" found in any well-equipped motion picture studio. The intensity of these lights is increased for high-speed work by operating the lamps as close to the melting point of tungsten as is practicable. The lamps are often relocated with respect to the focus of the reflector, so as to focus at shorter distances, thereby permitting the focusing of the filament directly on the subject. The illumination required varies according to the area to be photographed, the color of the subject, and the taking speed of the camera. In general, other factors being constant, the amount of light required will be in direct proportion to the taking speed, thus approximately 500 times as much light will be required to take pictures at a rate of 8000 per sec, as at 16 per sec. At the slower taking speeds, the intensity of light need not be so high; thus, with the camera operating at 2000 pictures per sec, photofloods such as the *R2*- and the *R3*-type lamps can be used. Pictures have been made at speeds in this range using a sequence of photoflash bulbs focused on the object and fired in rapid succession to keep the intensity peak constant. Arc lights may also be used in some cases.

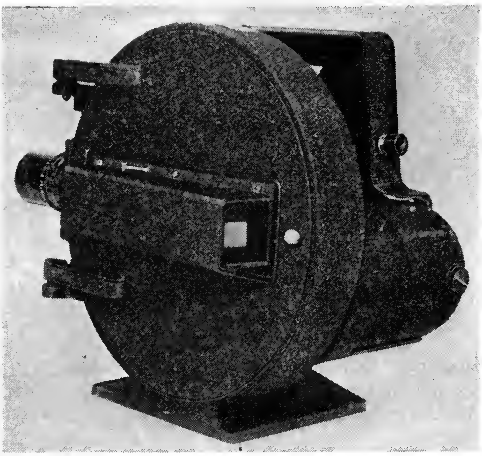


FIG. 11. Fastax camera closed. The view finder is mounted on the door.

The focused lights are arranged to accent the proper modeling of the subject, so as to be sure that the moving parts under study are receiving the full amount of illumination, and that the shadows of adjacent details are not obscuring the field of view. A typical arrangement of lighting units is shown in Fig. 7.

When the proper technique is used in lighting the subjects, the Fastax camera will produce clear, steady pictures that can be projected on any standard 8-mm projector, and have a fair depth of focus and good definition. The type of pictures obtained with this camera is illustrated in Fig. 8. These pictures were selected from a strip of 36 consecutive frames enlarged from an 8-mm high-speed motion picture film taken at 8000 frames per sec with the lens stopped down to $f/8$, and show 0.0045 sec of action of a telephone-type fuse known as the "grasshopper."

The final design of the camera is illustrated in Figs. 9, 10, 11, and 12. It is approximately 12 × 10 × 10 in. high and weighs about 40 lb, and is suitable for operation either in the laboratory or in the field.

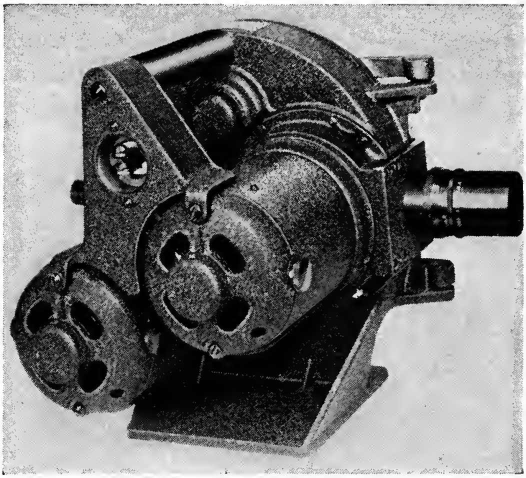


Fig. 12. Motor side of Fastax camera. The motor on the left drives the take-up spindle, and the one on the right drives the sprocket and compensating prism.

A substantial number of Fastax cameras have been made and are now in active use by industrial organizations, research laboratories, and various branches of the Armed Services.

References

[1] Eyles, E. D.: *J. Scient. Instruments*, **18** (Sept., 1941), p. 175.

[2] Connell, W. H.: *J. Scient. Instruments*, **4** (1926), p. 82.

[3] Jenkins, C. F.: "Motion Picture Camera Taking 3200 Pictures per Second," *Trans. Soc. Mot. Pict. Eng.*, **17** (Oct., 1923), p. 78.

[4] Jenkins, C. F.: "The Jenkins Chronoteine Camera for High-Speed Motion Studies," *Trans. Soc. Mot. Pict. Eng.*, **25** (Sept., 1926), p. 25.

[5] Tuttle, F. E., and Reid, C. D.: "The Problem of Motion Picture Projection from Continuously Moving Film," *J. Soc. Mot. Pict. Eng.*, **XX**, 1 (Jan., 1933), p. 3.

[6] "The Zeiss-Ikon High-Frequency Camera," *Brit. J. Phot.* (Sept. 27, 1935), p. 617.

[7] SUHARA, T.: *Proc. Imperial Academy Tokyo*, **5** (1929), p. 334.

[8] SUHARA, T., SATO, N., AND KAMEI, S.: "Report No. 60," *Tokyo University Aeronaut. Res. Inst.* (May, 1930), p. 187.

[9] TUTTLE, F. E.: "A Non-Intermittent High-Speed 16-Mm Camera," *J. Soc. Mot. Pict. Eng.*, **XXI**, 6 (Dec., 1933), p. 474.

[10] HERRIOTT, W.: "High-Speed Motion Picture Photography Applied to Design of Telephone Apparatus," *J. Soc. Mot. Pict. Eng.*, **XXX**, 1 (Jan., 1938), p. 30.

[11] TOWNSEND, J. R.: *Elec. Eng.*, **59** (Nov., 1940), p. 448.

[12] SMITH, H. J.: *Bell Lab. Rec.* **XXII**, 1 (Sept., 1943), p. 1.

[13] GALE, A. L.: *Movie Makers* (Feb., 1944), p. 54.

[14] JONES, L. A.: *Phot. J.*, **84** (Apr., 1944), p. 118.

[15] TAYLOR, H. D.: *Proc. Phys. Soc.*, **49**, 6 (1937), p. 663.

[16] EHRENHAFT, F., AND BACK, F. G.: "A Non-Intermittent Motion Picture Project," *J. Soc. Mot. Pict. Eng.*, **XXXIV**, 2 (Feb., 1940), p. 223.

THE PRESENTATION OF TECHNICAL DEVELOPMENTS BEFORE PROFESSIONAL SOCIETIES*

W. L. EVERITT**

[**Ed. Note.**—*The following article by Dr. W. L. Everitt, from the Proceedings of the Institute of Radio Engineers, is being reprinted at the suggestion of a number of our members as it presents very clearly and completely the methods which should be used in presenting technical information, either to an audience or in a technical publication.*

We know that this excellent article can be of great assistance to our members and other contributors to the Journal of the Society of Motion Picture Engineers.]

Summary.—*The professional man has an obligation to give wide dissemination to new discoveries and developments. This may be done by publication and by oral presentation before technical groups. The proper presentation of a paper requires the co-ordination of four groups or individuals. A check list of their duties is given which may be used as a reference in the planning of technical sessions.*

The natural result of professional activities, particularly in science and engineering, is the development of new ideas and methods which are important, not only to the solution of a special problem but also to the general development of the art. It is not only the *privilege* but also the *obligation* of the professional man to make this knowledge available to other workers in his field and to the general public at the earliest possible time compatible with his own interest or that of his employer. Except when military security dictates otherwise, this information should be given as wide and early dissemination as possible, since its originator cannot know to whom and to what extent this new knowledge may be useful for the benefit of mankind.

It is to the advantage of the engineer and of his profession first to present publicly important developments and ideas of general utility in his field before a recognized professional society, where they may be discussed, developed, and perhaps questioned by his associates. By so doing, the engineer may be spared embarrassment or even discredit to himself or to his professional associates which sometimes follows premature disclosure to the public press.

* Reprinted from *Proceedings of the I.R.E.*, **33**, 7 (July, 1945), p. 423.

** President, The Institute of Radio Engineers, Inc.

The general dissemination of new technical ideas to the profession should be done in one or both of 2 ways:

(*1*) By the presentation of a paper before a technical session of a professional society,
(*2*) By the publication of a paper in the journal of a professional society or in a technical magazine.

It is preferable that both methods be used for many developments. If the presentation is before a technical session where the attendance necessarily is limited, it is desirable to submit a paper for publication consideration to the society which sponsored the session, so that all members may be informed. When both methods are used, the published paper should include material which is developed in the discussion at the technical session, including a correction of errors which the discussion may bring forth.

Papers which provoke oral *discussion* are the type which will give the most profit to the author, the society, and the public by presentation first before a technical session. The papers committee in charge of the session, together with the author, should examine proposed papers with this point in view. The author should also keep this in mind in preparing his presentation. Unless early release is essential there is little profit to anyone merely in reading a paper before a group. Papers which require extended mathematical development, or detailed study to grasp their implications, are not suitable for presentation at technical sessions unless they can be briefed, and the important conclusions presented, so that the audience can participate in the discussion.

A strong distinction should be drawn between *reading* and *presenting* a paper before a technical session. The reading, word for word, of material which later is to be published, without adequate opportunity for discussion, as has been done all too often, is a waste of everyone's time and fulfills no useful purpose.

The proper presentation of a paper before a technical session requires the team action of at least 4 individuals or groups. They are usually

(*1*) The Papers Committee,
(*2*) The Arrangements Committee,
(*3*) The Chairman of the Technical Session,
(*4*) The Author.

A mutual knowledge of the duties and responsibilities of each member is desirable to obtain team action.

The following suggestions are proposed for the duties of the team members in the conduct of technical sessions. While they are intended primarily for convention sessions, where there are a number of authors, most of the suggestions are applicable to section meetings. If you are a member of such a team, use this as a check list to be sure you are performing your functions.

Duties of the Papers Committee.—The Papers Committee, or an individual performing its functions, determines:

(*1*) The general theme of the technical session (industrial electronics, radio antennas, *etc.*),
(*2*) The time and date of the session,
(*3*) The length of the session,
(*4*) The chairman of the session (and contacts and secures him),
(*5*) The number of papers,
(*6*) The time allotted to each paper,
(*7*) The proposed topics (examining them to be sure either that they can stimulate discussion, or that they should be presented to advance the date of release of the information).

The Papers Committee also

(*8*) Contacts the author to obtain the paper,

(Note: Items *7* and *8* may occur in either sequence.)

(*9*) Handles all correspondence with the author, forwards suggestions as to the author's duties, determines from him what aids such as lanterns, blackboards, motion picture projectors, power outlets, manual assistance, and the like, he will require in his presentation.
(*10*) Notifies the Arrangements Committee of the date and time, probable space required, and the requirements of the author in the way of lanterns, blackboards, and other supplies. Also indicates whether stenographic recording is desired.
(*11*) Arranges for the introduction of the chairman, unless he is a section officer or otherwise acting in an official capacity so as to be known to the audience.

Duties of the Arrangements Committee.—The Arrangements Committee, or an individual performing its functions, arranges for:

(*1*) The meeting place,

(*2*) The mailing of notices and other publicity (unless under the jurisdiction of a separate committee),
(*3*) Janitor service,
(*4*) Projectors, blackboards, chalk, erasers, pointers, *etc.*,
(*5*) The lantern operator,
(*6*) Smooth control of the darkening of the room from the lantern operator's position by remote control, or by signaling to an attendant at the room lighting switch,
(*7*) Means for signaling between the speaker and the lantern operator,
(*8*) A public-address system where (and only where) needed. (When provided, the public-address system should have a lapel microphone if at all possible.) Check that it is in proper operating condition and that the gain is set properly.
(*9*) Contact with the chairman of the session to apprise him of services provided and their operation, and to determine other services which may be desired. Inform him of any special conditions applying to the concluding of the session and vacating of the premises.
(*10*) Power outlets for demonstrations,
(*11*) Assistance for bringing in and removing demonstration equipment,
(*12*) Shipping instructions for the disposal of demonstration equipment after the meeting,
(*13*) Chairs,
(*14*) Tables,
(*15*) Reading lights,
(*16*) Distribution of material which is to be passed out to the audience (and its collection if necessary),
(*17*) Recording of attendance, if desired,
(*18*) Stenographic recording of discussion, if desired,
(*19*) Meeting of the speaker at section meetings, if he comes from out of town, and making sure that his time is occupied to fit his convenience. (Have this done by a friend of the speaker if possible.)

Duties of the Chairman of the Technical Session.—The Chairman:

(*1*) Presides at the meeting and is responsible for the tempo and character of the whole session, (*2*) Introduces speakers and outlines method of conducting discussion,

(*3*) Contacts authors, lantern, and light-control attendants in advance of the session to acquaint them with each other and with himself and to issue special instructions, including information on

- (*a*) Facilities available,
- (*b*) Method of disposition of lantern slides,
- (*c*) Method of signaling operators,
- (*d*) Time schedule and method of adherence thereto,
- (*e*) Operation of public-address system,
- (*f*) Location of pointers, chalk, erasers, and any other supplies,
- (*g*) Method of conducting discussion.

(*4*) Ascertains from authors whether they know of members who will discuss papers,

(*5*) Receives information from members who have prepared discussions,

(*6*) Conducts business where such is scheduled,

(*7*) Is *responsible* for adherence to time schedule,

(*8*) Calls for discussion,

(*9*) Recognizes discussors in order, giving preference to those who have indicated preparation in advance. At conventions, he makes sure each speaker on the floor stands up and gives his name and business connection clearly. If he cannot be heard, the chairman should require him to come forward and face the audience and to use the public-address system if possible. Remember, a member of the audience in the center of the room has his back to half the audience.

(*10*) Makes sure that questions from the audience are heard by all, and repeats them if necessary before the author replies,

(*11*) Confines discussion to the topic,

(*12*) Closes discussion when completed or at expiration of allotted time,

(*13*) When desirable, requests that discussions, containing comments which are important, be submitted in written form to the author and to the Editor of the *Proceedings*. Forwards to the Editor discussions which are available in written form at the time of the meeting.

Suggestions to the Author in the Presentation of a Paper before a Technical Session.—It is beyond the scope of this article to develop the rules for effective public speaking, as there have been many publications on this subject. However, it is believed that adherence to certain technical and almost mechanical rules will improve the presentation of any paper. The following suggestions apply. Remember that a stimulating discussion is beneficial to the author, the audience, and the society.

(*1*) Prepare a draft of the paper in advance. Keep in mind that your mission is to teach rather than to demonstrate how much you know. Be sure the paper is presented from a professional viewpoint and not as an advertisement of your commercial connections. *Make it interesting.* Your efforts are wasted if the audience is bored.

(*2*) Appear at the meeting sufficiently in advance of the scheduled time to meet and confer with the chairman.

(*3*) *Do not read the paper.* Brief it and present it orally, emphasizing its high points, especially any items over which there may be controversy. Be sure the material is in logical sequence.

(*4*) Speak clearly and distinctly, look at your audience, and evidence your interest in them and in your subject.

(*5*) Show the relation of the development discussed to the progress of the art.

(*6*) Distribute properly the time assigned to oral presentation, demonstration, and discussion.

(*7*) Practice and time yourself beforehand.

(*8*) Adhere to the time schedule. Expect the chairman to require you to do so. Use a watch which is constantly within your view. Modify your talk if you find you are running overtime.

(*9*) Arrange for demonstrations if possible; they always provoke more interest.

(*10*) Notify Papers Committee of lanterns, blackboards, power outlets, and other facilities you will need.

(*11*) Provide adequate illustrations, preferably on standard $3^1/_4$- × 4-in. lantern slides. You may have to provide your own projector if nonstandard slides are used. Be sure the thumb marks are properly placed, and the slides are in order with the thumb marks facing the operator and in the upper right-hand corner. Use a slide container which will keep all slides in order.

(*12*) Use simplified block diagrams on slides where possible. Do not put too much detail on any slide; it is confusing in the short time during which it is shown. (This cannot apply to photographs of equipment.)

(*13*) Make proper use of the public-address system. Keep at a constant distance from the microphone and in the same relative position at all times. Even if you have a powerful voice, it is disconcerting when the public-address system fades out due to increased separation of the speaker from the microphone, or due to the turning of the head.

(*14*) Never turn your head away from the audience while you are talking, even to point out items on the projection screen, unless you are wearing a lapel microphone. If necessary, point to the screen and then turn and speak into the microphone or towards the audience.

(*15*) Use the facilities provided to signal the lantern operator and point to the screen.

(*16*) Give credit to others who serve as a source for your statements.

(*17*) Make clear which statements you consider facts and which you consider conclusions or opinions.

(*18*) In advance of the meeting, send copies of your manuscript to competent members who may attend the meeting. Ask them to come prepared to take part in the discussion. Do this particularly to individuals who may differ with you or oppose your views. Opposition may develop interest in your ideas and promote their acceptance if they are worth while, or save you from embarrassment later if you are in error. Notify the chairman of the meeting of any discussion you expect, and help him contact their source.

(*19*) Rewrite your paper for publication, giving consideration to the points which were developed in the discussion. Send at least 3 copies to the Editor of the *Proceedings* as soon as possible.

(*20*) Secure copies of the discussions in typewritten form, if possible. The chairman may assist you in this.

Again, and above all, *speak clearly and logically and adhere to the time schedule.*

EFFICIENCY OF PICTURE PROJECTION SYSTEMS

EDWARD W. KELLOGG*

Summary.—*The very small fraction of the total lamp output which finally reaches the screen from a projector might lead one to question the design of optical systems of the type now in general use. Nevertheless there does not seem, with present light sources, much chance of radical improvement. For practical purposes efficiency, in the sense of the ratio of screen lumens to total lamp lumens, is of much less consequence than screen brightness and picture quality. The benefit from improved efficiency is not necessarily a brighter picture, but more often the ability to work with a lamp of lower wattage. A designer may be justified in increasing the light wasted within his projector, for the sake of obtaining a proportionately smaller improvement in screen brightness.*

Other writers have discussed design from the standpoint of producing the best picture. The present paper is largely confined to the subject of calculating efficiencies for such interest as it may have in showing where the light losses occur. The conclusion is reached that an optical system, designed for maximum screen lumens, is doing well from the efficiency standpoint if it projects to the screen more than 2 or 3 per cent of the total lamp output.

Approach to Problem.—During the discussion of John A. Maurer's paper on "The Optics of Motion Picture Projection" at the SMPE Technical Conference in New York in May, 1943, it was brought out that only about 5 per cent of the light emitted by the source reached the screen. This is a surprisingly low figure and would on first thought lead one to question whether an optical system which did not do better than this had been well designed. Before reaching any inference of this nature, one should recognize that designers of optical systems are far more concerned about the total light reaching the screen than about the efficiency of the system, or ratio of screen light to total lamp output. If, for example, the designer can add 20 per cent to screen brightness by adding 100 per cent to the lamp wattage, he will in general do so. He will have a better projector, although his system will be of lower efficiency, using the word efficiency in the strict sense of ratio of useful output to total supply. Stimulated by the discussion just mentioned, the writer has made some calcula-

* RCA Victor Division, Radio Corporation of America, Indianapolis, Ind.

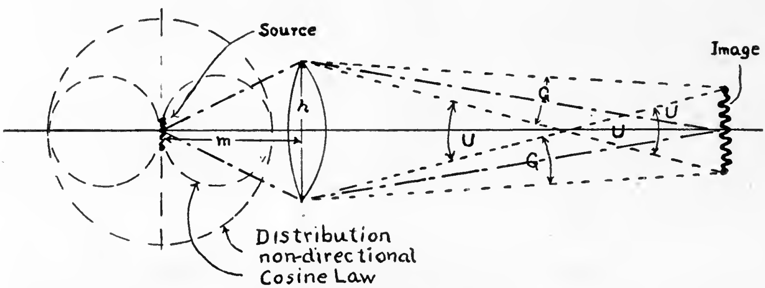
tions in an effort to see where the 95 per cent goes, and believing that the calculations are of some interest, they are being offered in this paper. Briefly speaking, the calculations are to answer the questions:

(*1*) What fraction of the total lumens radiated by the lamp would enter condensing lenses of several different numerical apertures (or subtending different angles from the source)?

(*2*) What proportion of the light passing through the condenser lens goes through the picture gate, and what fraction strikes the surrounding surfaces?

(*3*) Of the light which passes through the picture aperture, what fraction enters the projection lens?

Among the references [1-6] listed at the end of this paper the reader will find discussions of the general problems of projection optics and studies of various special problems.



U = Region of uniform intensity.
G = Region of graded intensity.

FIG. 1. Angle subtended by condenser, and character of beam.

Two Types of Optical Systems.—There are 2 fundamental types of optical systems, in which,

(*1*) The light source (filament or arc crater) is imaged by the condenser system in the picture gate;

(*2*) The light source is imaged in the projection lens and the condensing lens system is preferably as close to the picture aperture as practical considerations permit.

It is also possible to design a system with the light source image between the picture gate and the projection lens, and such systems are common, but it is thought to be unnecessary to attempt here to calculate such a system. The figures for light losses would in general be intermediate.

Collection of Light by the Condenser Lens.—The first problem, which applies to both types of optical systems, is to collect as much of the light from the lamp as practically possible and concentrate this in the filament image just mentioned. This means designing the condensing lens to subtend a large angle from the lamp. Calculations were made for only 2 types of radiation characteristics, nondirectional (or uniform in all directions) and bidirectional, or obeying Lambert's cosine law, such as would result if the source were a thin flat plate of hot tungsten. The monoplane lamp is an approximation to this.

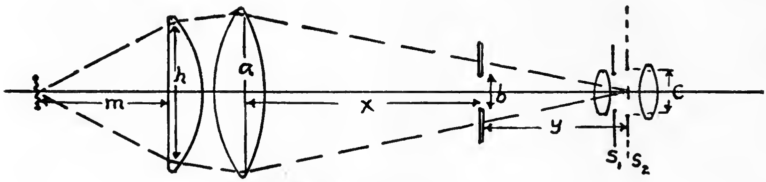
Table 1 gives the fraction of the total radiation of the lamp which would be intercepted by condenser lenses working at $f/1.5$, $f/1$, $f/0.85$, and $f/0.75$. The term f-number is here used as the ratio of diameter to working distance, or h/m as illustrated in Fig. 1. It has been assumed in the calculations that the light radiated in the opposite direction is not utilized. This is very nearly true of the biplane lamp, in which the principal contribution of the mirror is in filling in some low spots; but in the case of multifilament monoplane lamps, properly adjusted mirrors can add to the useful light by an amount which is probably of the order of 60–70 per cent. No allowance is made here for the imperfections of the lenses which would cause some further losses.

TABLE 1

Fraction of Total Light Intercepted by Condenser (Cols. 3 and 4)

f number	Condenser Included Angle (Degrees) Measured from Axis	Lamp Characteristics Nondirectional	Lamp Characteristics Cosine Law
1.5	36.8	0.025	0.05
1.0	53.0	0.052	0.10
0.85	61.0	0.069	0.129
0.75	67.4	0.084	0.154

Requirements for Full Illumination.—It has been assumed for the purpose of calculation that the projection lens must be utilized at its full aperture and also that all parts of the picture aperture must receive full illumination. In practice a compromise is usually made in the way of reduced brightness at the corners of the screen. This permits considerable reduction in the total amount of light required, but the formulas I have used can be applied to such a case by simply assuming a reduced diameter for the picture aperture, this reduced diameter being that of the portion of the picture which does receive full illumination. The calculation of light losses at the gate or projection lens is purely a geometric one involving 3 apertures, (*a*) the condenser lens (its exit pupil), (*b*) the picture aperture, and (*c*) the projection lens (entrance pupil). The condition of complete illumination of the picture aperture and complete utilization of the projection lens imposes a size requirement on the condenser. The condenser lens must be large enough so that there will be no point within the



S_1 = Lens stop.
S_2 = Virtual image of S_1.

FIG. 2. Optical system, with filament imaged in projection lens.

projection lens stop, from which the edge of the condenser lens pupil can be seen through the picture aperture. This cannot be true unless the rim of the condenser falls outside the diagonal lines *d*, *d*, shown in Fig. 3. Or, to express it differently, from any point within lens *C* of Fig. 3 the picture aperture should appear to be completely filled with light coming from the condenser lens. (See dotted lines through point *P* in Fig. 4.) If the conditions just described are met, the screen

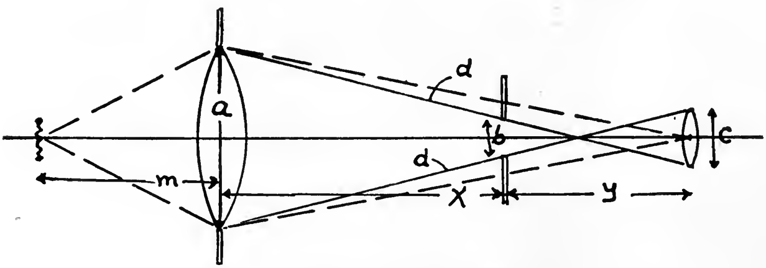


FIG. 3. Simplified version of Fig. 2.

brightness will be the same and therefore the useful light will be the same, whether the filament is imaged in the projection lens or in the picture aperture or, for that matter, in between. In other words, it is possible to achieve the same final result with either system No. 1 or No. 2 (assuming the light source to be of such uniformity that No. 1 can be considered). This is not saying, however, that the result will be obtained with the same sized lamp.

To provide a specified screen brightness, the designer first chooses a projection lens of the desired focal length and of the necessary aperture. The condenser is then designed of sufficient diameter in relation to its spacing from the picture aperture to comply with the requirements just discussed, and of as short focal distance on the lamp side as is considered practical, and with the filament magnification ratio thus determined, a lamp must be chosen constituting a sufficiently large source so that its image will fill the picture aperture or the projection lens (whichever the chosen system calls for). Spherical

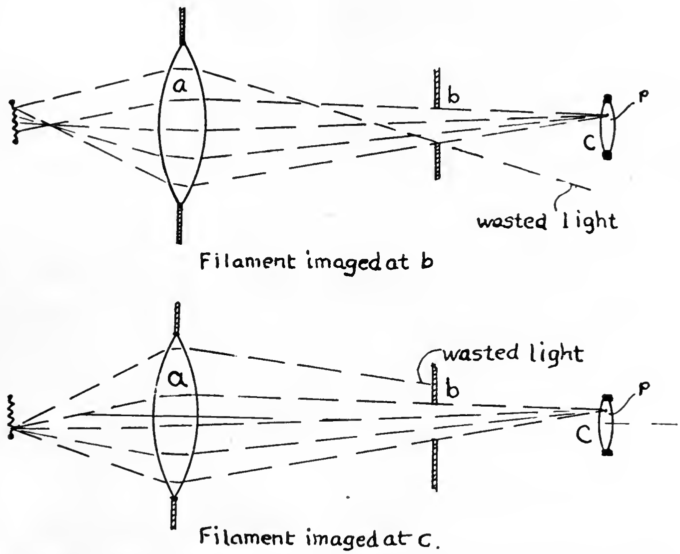


FIG. 4. Conditions for complete illumination of picture aperture.

aberration in the condensing system may make it necessary to provide some margin in condenser size, or else cause some loss of brightness, usually at the corners of the picture. The calculations presented here do not make any allowance for spherical aberration, but this should scarcely alter conclusions as to the relative efficiencies of various arrangements. Moreover, we set out to ascertain what wastages are practically unavoidable, even with the best of lens designs.

It is evident that if the design procedure just outlined is followed, the penalty for unnecessary wasting of light in the optical arrangements is the necessity of using a larger lamp to produce a given picture illumination.

Calculation of Condenser Diameter.—The first step in estimating light losses at the picture and projection lens apertures, is to calculate, for any assumed sizes and spacings of these apertures, how large a condenser lens will be required. The size of the condensing lens with the size and distance of the image of the filament produced by it determine the total light which the condenser lens must collect. If,

a stands for the diameter of the condenser lens (exit pupil),
b stands for the diameter of the picture aperture (diagonal if aperture is rectangular),
c stands for the diameter of the projection lens (entrance pupil),
x stands for the distance from condenser to picture aperture,
y stands for the distance from picture to projection lens,

the diameter of the condenser to meet the illumination requirements stated above is given by the following formula which is simply an algebraic statement of the geometrical construction shown in Fig. 3:

$$a = c\frac{x}{y} + b\left(\frac{x}{y} + 1\right).$$

It is worthy of note that the required condenser size (for given values of b, c, x, and y) is independent of whether the filament is imaged in the gate or the projection lens. However, the total amount of light which the condenser must collect will not necessarily be the same in the 2 cases, the size of the lamp and distance from lamp to condenser being chosen to produce a filament image of the required size to fill the gate or the lens as the case may be.

Light Losses at Picture and Projection Lens Apertures.—Of the light collected by the condenser, only a fraction passes through the picture aperture and projection lens. It is next of interest to estimate how much is thrown away, either around the picture aperture or around the projection lens. There is a well-known expression for total light transmitted through 2 coaxial apertures. If a source has a brightness B candles per sq cm and area A_1 sq cm, it will radiate BA_1 lumens into each unit of solid angle (steradian). If it illuminates an area A_2 sq cm l centimeters away, the solid angle subtended by A_2 is A_2/l^2. Then the number of lumens passing from A_1 through A_2 is approximately (assuming l^2 is substantially larger than A_1 or A_2):

$$L = B\frac{A_1A_2}{l^2} \qquad (1)$$

This expression is applicable only when the optical arrangements are such that the light intensity is uniform at A_1 and A_2.* Such a condition holds when A_1 is taken at a condensing lens and A_2 at the image of the source, provided the source is of substantially uniform brightness. If the source comprises a series of parallel filaments, it will not be uniform, but an average brightness may be taken for the source provided A_2 is large enough to include several coil images.

The purpose of our calculations is to show what light losses are unavoidable in the system and not to include any which are unnecessary. Therefore, it is assumed that the filament image is of the correct shape and just large enough to fill the picture aperture in the case of system No. 1, or to just fill the projection lens in system No. 2. The correction for shape factor is discussed later, but without such a correction it is possible to draw certain general conclusions, for which purpose we shall for the present assume circular apertures throughout and assume a circular light source image.

The total light transmitted by the condenser may be calculated, using formula (1), with A_1 standing for the condenser lens exit pupil, A_2 the filament image area, and l the distance between them.

The useful light is calculated from the same equation, letting A_1, A_2, and l stand for the picture gate area, the projection lens aperture area, and l the distance between them, or using the symbols shown on Fig. 3, the useful light is

$$\frac{(0.7854b^2)(0.7854c^2)}{y^2}$$

for a circular aperture at b.

The ratio of total light transmitted by the condenser to the useful light, may be calculated for the case of a circular picture aperture and light source by the following formulas:

Optical System Type 1

Filament imaged in picture gate, just covering latter.

$$\frac{\text{Total}}{\text{Useful}} = \left[1 + \frac{b}{c}\left(\frac{x+y}{x}\right)\right]^2 \qquad (2)$$

* So that it may be said that there are rays from all parts of A_1 to every part of A_2. If the intensity of the light beam is uniform throughout its cross section at A_1 and at A_2, then at positions between A_1 and A_2 and also for a short distance beyond A_2, the light beam cross section has a central area of uniform brightness, as indicated in Fig. 1, and an outer zone in which the intensity tapers off to zero at the outer edge. Hence, the cross section of the beam at such a point may not be used in calculating transmitted light. When large angles are involved, or in other words unless l is several times $\sqrt{A_1}$ or $\sqrt{A_2}$, formula (1) is approximate only.

Optical System Type 2

Filament imaged in projection lens, just filling latter.

$$\frac{\text{Total}}{\text{Useful}} = \left[1 + \frac{c}{b}\left(\frac{x}{x + y}\right)\right]^2 \qquad (3)$$

The formulas serve well to bring out the conditions under which each system operates to best advantage. For minimum light loss, the second term within the parentheses must be made small. Thus, in system No. 1 the wasted light is minimized when the projection lens is large and the picture aperture small. There is a further advantage in working with the condenser well back from the picture gate.

In the case of system No. 2, it is possible (with circular picture aperture) to reduce the wasted light to a small value by making x nearly zero or, in other words, placing the condenser adjacent to the picture aperture. There is objection to doing this because any dirt or scratches on the condenser would be sharply focused on the screen. Therefore, this term cannot be made equal to zero, and the ratio of projection lens to picture aperture diameter is an important factor, efficiency being favored by large picture aperture and small projection lens, which is not the usual condition with motion picture projectors. However, with practical dimensions in 16-mm projectors, the balance is not seriously unfavorable to system No. 2, provided the condenser does not have to be too far back from the picture gate.* With incandescent lamps, the source is too irregular to image in the gate, and therefore we are practically limited to system No. 2.

In system No. 1, the excess light goes through the picture aperture and is thrown away around the outside of the projection lens. In system No. 2, the wasted light is intercepted by the picture aperture plate.

There are further losses owing to the fact that the picture aperture is a rectangle instead of a circle and the fact that the image of the source may not be the same shape as the aperture in which the image is formed. System No. 1 is widely used with arc lamps, and the arc image must much more than cover the rectangular picture aperture in order to insure uniform illumination throughout the picture. In the case of system No. 2 there would be minimum loss with a circular light source whose image would just fill the projection lens, and so far as the sources are not circular, the source image must be oversize.

---

* Compare, for example, the total to useful light ratio of Cases *4* and *5* with Cases *1* and *2*.

There is no way in system No. 2 to avoid the loss because of the fact that the pictures are rectangular. The total light required is the same as for a circular aperture whose diameter is equal to the diagonal of the rectangle. The useful light is reduced in the ratio of the area of the rectangle to that of the circle.

Table 2 shows values of the ratio of total light transmitted through the condenser to that which is transmitted through the projection lens to the screen, calculated by formulas (2) and (3). No allowance is made for reflection losses at glass surfaces.

The arrangement described by F. E. Carlson[4] is an interesting combination of the 2 systems, in which a cylindrical or toroidal surface is used in the condensing system to bring the filament image into the plane of the gate in the vertical direction (in which the uniformity of the source is excellent) while in the horizontal plane the filament is brought to focus in or near the projection lens. Mr. Carlson found a 15 per cent increase in screen brightness obtainable by this expedient. Since it is presumable that the projection lens was filled in both directions before the introduction of the cylindrical surface, the extra light output may have resulted from the fact that the new system derived its light from the middle portions of the filaments which were hotter than the ends.

Figs. 5 to 10 show the relative dimensions of the several systems compared in the table, and also the over-all efficiency of each arrangement, assuming the picture aperture to be 0.3 × 0.4 in. and the light source approximately circular, with cosine law distribution, and based on a condenser system working at $f/1$ with respect to the lamp, or collecting 10 per cent of the total lamp output. It is not exactly fair to assume the same collection angle for the condenser, for in system No. 1 the filament image must be formed nearer the condensing lens than in system No. 2, making it in general necessary to increase slightly the spacing between the filament and condenser, or else use a stronger condenser of the same diameter.

Case *7* illustrates improved efficiency at the sacrifice of screen brightness, by showing the reduced ratio of total to useful light, which in system No. 2 is obtainable when the projection lens is slow. Observe that for $x = y$ and the projection lens twice the diameter of the maximum dimension of the picture aperture (Cases *1* and *4*), system No. 1 shows no better efficiency than No. 2, but that with faster projection lenses or with x exceeding y, system No. 1 increases in efficiency while system No. 2 loses.

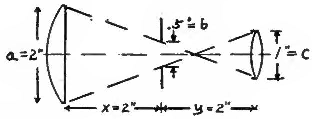
TABLE 2

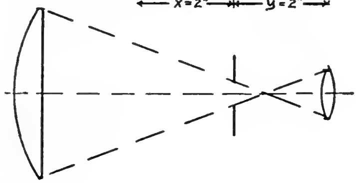
Case	System	Image Location	Proj. Lens	x (In.)	y (In.)	a Required (In.)	b (In.)	c (In.)	Ratio, Total Light from Condenser to Useful Light: Circular Aperture, Circular Source	0.3 × 0.4-In. Aperture: Circular Source	0.3 × 0.4-In. Aperture: 0.3 × 0.4-In. Source	See Fig.
1	1	Gate	$f/2$	2	2	2	0.5	1	4	6.55	*4	5
2	1	Gate	$f/2$	4	2	3.5	0.5	1	3.1	5.1	*3.1	6
3	1	Gate	$f/1.6$	2	2	2.25	0.5	1.25	3.25	5.35	*3.25	7
4	2	Lens	$f/2$	2	2	2	0.5	1	4	6.55	..	5
5	2	Lens	$f/2$	1	2	1.25	0.5	1	2.88	4.7	..	8
6	2	Lens	$f/1.6$	2	2	2.25	0.5	1.25	5.05	8.3	..	7
7	2	Lens	$f/4$	2	2	1.5	0.5	0.5	2.25	3.7	..	9
8	2	Lens	$f/2$	2	2	1.6	0.3	1	...	**4.75±	..	10

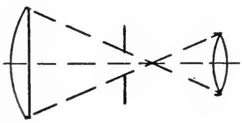
* These figures are given as the same as for a circular aperture to bring out the condition that, were it possible to use a source of the same shape as the picture, there would not need to be any light thrown away at the gate. It is not fair to compare these figures with those for system No. 2, for no such source is available at present.

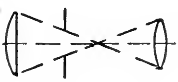
** Case *8*—If full illumination is provided for only a 0.3-in. circle in the 0.3 × 0.4-in. aperture, the total light to be collected by the condenser could be reduced to about two-thirds of that required for complete illumination of the rectangle (Case *4*), and the illumination at the corners of the screen would be down about 20 per cent. This represents a comparatively small reduction in total screen lumens (not readily calculated, but of the order of 8 per cent), whence the ratio of total to useful light would be about 4.75 as compared with 6.55 for Case *4*.

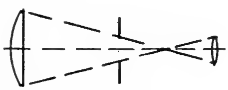
Even with the optimistic conditions assumed for these calculations, the over-all efficiencies are seen to be very low, so that the 5 per cent mentioned at the beginning of the paper would be excellent. Practically obtainable efficiencies would be less than calculated because of glass-air surface reflections, condenser aberrations, and filament shape

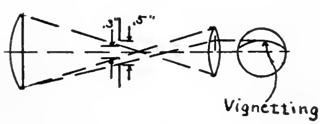












	Fil. Image at	Over-all Eff. (%)
FIG. 5:		
Case *1*	*b*	1.5
Case *4*	*c*	1.5
FIG. 6:		
Case *2*	*b*	2.0
FIG. 7:		
Case *3*	*b*	1.87
Case *6*	*c*	1.2
FIG. 8:		
Case *5*	*c*	2.1
FIG. 9:		
Case *7*	*c*	2.7
FIG. 10:		
Case *8*	*c*	2.1

factor. On the other hand, in an incandescent lamp system a properly adjusted reflector would give an improvement not considered in the calculations, and partially offset the extra losses just mentioned. The reflector not only raises efficiency but also improves screen brightness and uniformity.

No attempt has been made here to calculate efficiencies of arc light systems, but considerably higher efficiencies are obtainable, partly because the source inherently radiates the major part of its light in one direction, and partly because the source is sufficiently uniform to be imaged at or near the picture aperture. It is seen from formula (2) that a relatively large projection lens and small picture aperture (as is true of 35-mm projectors) as well as large ratio of x to y are favorable to the minimizing of light losses in system No. 1.

REFERENCES

[1] HARDY, A. C.: "The Optics of Motion Picture Projectors," *J. Soc. Mot. Pict. Eng.*, **XIV,** 3 (Mar., 1930), p. 309.

[2] MILI, G., AND COOK, A. A.: "Condensers for 16-Mm Optical Systems," *J. Soc. Mot. Pict. Eng.*, **XXVI,** 6 (June, 1936), p. 603.

[3] MILI, G.: "Effect of Light-Source Size with 16-Mm Optical Systems," *J. Soc. Mot. Pict. Eng.*, **XXVIII,** 2 (Feb., 1937), p. 164.

[4] CARLSON, F. E.: "A Higher Efficiency Condensing System for Picture Projectors," *J. Soc. Mot. Pict. Eng.*, **XXXI,** 2 (Aug., 1938), p. 187.

[5] CARLSON, F. E.: "Properties of Lamps and Optical Systems for Sound Reproduction," *J. Soc. Mot. Pict. Eng.*, **XXXIII,** 7 (July, 1939), p. 80.

[6] COOK, A. A.: "Optics of Projectors for 16-Mm Film," *J. Soc. Mot. Pict. Eng.*, **XVIII,** 4 (Apr., 1932), p. 461.

TECHNICAL PROBLEMS OF INTERPRETATION IN PRODUCING FOREIGN-VERSION FILMS*

T. Y. LO**

Summary.—*To use motion pictures to enlighten international understanding, foreign-version films have to be considered in order to stimulate the local interest. Instructional and informational films can be changed into other languages either by narration or captions. It will be of more interest to the audience if life-dialogues in instructional films are synchronized with actors' lip movements into other languages, provided it is well done. Entertainment films are restricted to captions translating the dialogue.*

The author proposes that the picture area be reduced to provide a space at the lower margin of the screen for captions. A reduction printer must be developed for the process.

General George C. Marshall recently said that the second World War has seen the development of 2 new weapons: the airplane and the motion picture. In the China Security Plan offered to the Allies at Dumbarton Oaks in Washington, the motion picture is again emphasized as a vital medium in attempting to promote international friendship and understanding for maintaining world peace.

If the motion picture can be used effectively to kill and destroy, how much more can this medium do to teach men how to build, both physically and mentally, for a great future. The motion picture can show well the appearances of things and actions, but without the necessary interpretation to enable the audience to comprehend the motives and meanings underlying the actions, much of the picture will be meaningless. The value of the spoken word will be lost; instead of assisting to bring peoples together the very reverse may happen—the audience attempting to understand and not being able to do so, may become dissatisfied and even disgusted, and may probably give up all future attempts to understand. One may say, in effect, "Why should I be annoyed? I can't understand it, and the producer doesn't seem to care whether I do or not."

---

* Presented Oct. 18, 1944, at the Technical Conference in New York.

** Chinese Supply Commission, Washington, D. C.

Another point of importance is the manner in which the interpreting is done. It is bad to splash an interpretive caption across a beautiful picture—the photography is ruined and the attention is distracted. If the interpretations are on a separate screen alongside the picture, the eyes must dance a jig back and forth from the picture screen to the caption screen; there is a great contrast of light and dark that is annoying and fatiguing, and altogether the whole thing is unsatisfactory.

Educational and informational films form the subject of this paper, not so much from the point of view of content or the manner of presenting the material in picture and word form, but from the point of view of making such films fulfill their complete purpose when presented to a foreign audience. In adapting educational and informational films for foreign audiences only the sounds are changed—sound track, or titles, or both—from the one language to the other. However, it may not always be well to change the sound track; for example, if we were to show a Chinese audience a newsreel of Franklin D. Roosevelt making a speech—in English, of course, because I doubt that Mr. Roosevelt could speak Chinese—it would be unreal and even misleading to use a sound track in Chinese synchronized to Mr. Roosevelt's lip motions. The original sound track in English must be used in such an instance, even though the audience will not understand it. The only thing that can be done is to use superimposed captions or translations of what is being said.

There are 2 ways in which titles or translations are added to the films nowadays. One method has already been mentioned: the translation is photographed on a separate film from the picture film, and the two are printed together onto a duplicate negative to be used for making foreign release prints. This method puts the captions or translations on the picture area, as discussed previously. Another way of accomplishing the same effect is used currently in China: zinc engravings of the captions are made, and are pressed against the film, frame by frame, in a step printer, with a special chemical solution for removing the emulsion. This method has been used in cases where the important release prints were limited to only a few—say, two or three—in order to avoid large import duties and also to permit making the translations to suit the local uses and needs.

Educational pictures in which the dialogue consists of technical instruction are suitable for lip-movement synchronization. The U. S. Chinese Version Training Films produced by the U. S. Army Signal

Corps in cooperation with the Chinese were lip-synchronized, and were well received in China. The Chinese Army, especially, found much interest in these films. The job of synchronizing lip movements is difficult, but the audience finds additional interest in the film when a lecturer, foreign to the audience, uses a language other than his own to give instruction—provided the synchronization is well done. If it is not well done, it may as easily distract attention.

FIG. 1. Foreign-version picture with Chinese caption.

In order to synchronize lip movements it is necessary to divide the film into short sections—the shorter the easier. Each section to be synchronized is made into a loop and is run over and over again while the synchronizers become familiar with it, and rehearse it over and over again until their lip movements synchronize perfectly with the lip movements of the actors on the screen. It has been found helpful also to draw curves in ink on the work print indicating the opening and closing of the lips. The synchronizer sees this curve moving right and left over the picture as he views the work print. This procedure helps the synchronizer to follow the tempo, and also eliminates the difficulty of seeing accurately the lip movement in long shots.

As indicated before, superimposed titles and lip synchronization are not suitable for entertainment pictures. Entertainment pictures have dramatic values and special treatment for creating realism, and any disturbance of the senses by artificial sounds or vocal cadences will destroy the illusion that the producer hoped to instill in the minds of the audience.

FIG. 2. Chinese picture with English caption.

It is hardly necessary to raise again the question of how much of the photographic beauty of the picture is spoiled by putting translations into the picture area. And, in addition, it is often difficult to read such captions, when they are printed in white on a light background. There is also the difficulty of trying to synchronize the lip motions, as even a perfect synchronization cannot retain the dramatic quality and realistic feelings. Imagine trying to put into another language some of the emotional difficulties that Bette Davis portrayed in *Mr. Skeffington!* Some American pictures I have seen that were dubbed in French have been entirely ruined dramatically. It is my belief that entertainment pictures should neither be dubbed in foreign languages nor have foreign-language captions or titles printed in the picture area. Such things should be restricted to educational and informational films.

With regard to entertainment films, Figs. 1 and 2 show an arrangement proposed by the author which will avoid most of the difficulties discussed above. It is the simple expedient of optically reducing the picture during printing so as to leave sufficient space beneath the picture for titles and translations. The picture is reduced in the same

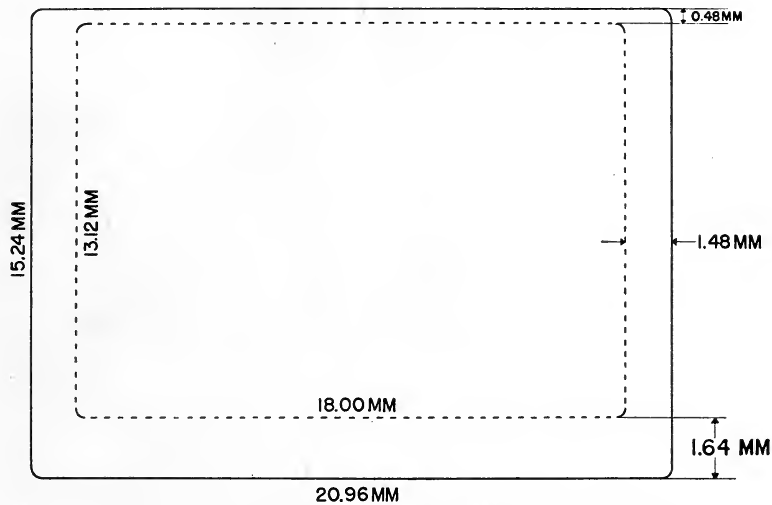


FIG. 3. Reducing dimensions based upon SMPE recommended projector aperture dimensions.

proportions as given in the SMPE Recommended Practice for projector aperture.

The reduction in size of the picture will be only 14 per cent—that is, the reduced picture will be about $^7/_8$ the size of the standard picture, and will have the same proportions as the original. With this reduction a lower margin of 15 in. will be left at the bottom of the picture on the screen image $20' 2'' \times 14' 6''$, which is the size of image thrown by a $4^1/_2$-in. lens at a distance of 110 ft. Fifteen inches will be adequate for 2 lines of Chinese characters and 3 lines of English. The English letters can be made about 4 in. high (allowing separation between lines) and 110 ft will subtend an arc of about 10 sec, which is more than sufficient for legibility.

If the theater manager for some reason or other does not like the 14 per cent reduction in size of picture image, he can install the next larger size screen and use a 4-in. lens whenever he shows the foreign-version films. The 4-in. lens will provide 11 per cent more magnification, so that the loss of screen image size will be only 3 per cent. The reduction in image brightness in either case will not be important. If the theater is to show both native and foreign-version films, a system of movable masks can be used around the edges of the screen. This may not be necessary, however, as it is proposed to print the captions and translations so as to appear on the screen in white on a black background in harmony with the black masking.

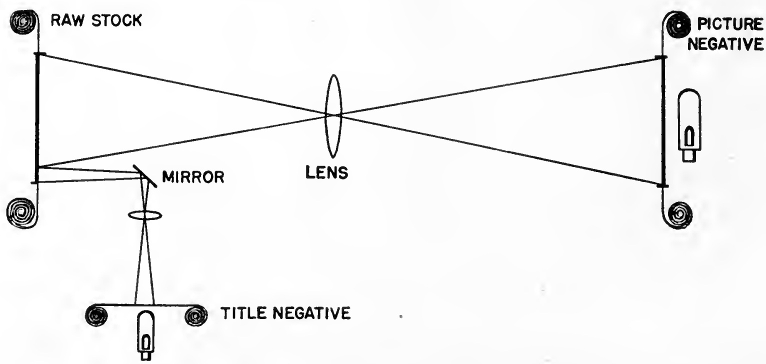


Fig. 4. A suggested method for printing foreign-version picture and caption.

Based upon the reduction of $^7/_8$ size (more exactly 86 per cent), the actual size of the picture image on the film will be 18.00 × 13.12 mm. The lower margin will be 1.64-mm wide and the top margin 0.48 mm. The side margins will be 1.48-mm wide. The total frame area will be the same as the SMPE Recommended Practice, *viz.*, 20.96 × 15.24 mm. Fig. 3 shows these dimensions.

A new optical printer is needed for such a process, the design of which should be left to the printer experts. Several arrangements should immediately suggest themselves, such as the use of masks or by simultaneous projection of picture and titles by separate optical systems (see Fig. 4). The new optical printer should find world-wide application, and all the countries of the world could produce their own foreign-version films locally from duplicate negative supplied by the producing companies.

SOME RELATIONSHIPS BETWEEN THE PHYSICAL PROPERTIES AND THE BEHAVIOR OF MOTION PICTURE FILM*

R. H. TALBOT**

Summary.—*It is impossible to attain absolute dimensional stability of an image on ordinary photographic films. There will be slight, but nevertheless measurable, distortions of the image owing to the loss of volatile materials and to the expansion or contraction which accompanies changes in moisture content. Likewise, a small amount of image distortion occurs frequently in printing.*

These distortions are usually quite small and can often be neglected. In certain specialized fields, however, they cannot be overlooked. In one part of this paper the various sources of these image distortions are discussed individually and suggestions are offered as to the manner in which these distortions may be minimized.

Another part of the paper is devoted to a discussion of the drying of motion picture film and the difficulties frequently encountered when the film is reeled with the emulsion layer in equilibrium and the base in partial equilibrium with the air in the drying cabinet.

In a previous paper, J. M. Calhoun[1] has discussed the physical properties of motion picture film and the extent to which these properties are influenced by heat, moisture, and other factors. It is the purpose of this paper to consider the relation of a few of these film characteristics to certain problems in the laboratory and in the theater projection room. The problems selected for discussion are image distortion and film defects resulting from insufficient drying.

As a rule, a small amount of distortion of either the negative image or the positive image does not detract noticeably from the usefulness of the motion picture print. There are, however, certain special fields in which the matter of image distortion has become increasingly important. These fields include color photography, special-effects photography, and certain applications of photography for military use.

An image on photographic film should not be considered as stable

* Presented Feb., 23, 1944, at a meeting of the Atlantic Coast Section of the Society in New York.

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

as one on glass or steel. Actually, the image on a piece of film is changing in size or shape continually throughout its life. Distortion of the photographic image is generally the result of shrinkage owing to loss of volatile materials, expansion or contraction produced by changes in moisture content, and failure of the printer to transfer the exact dimensions of the negative image onto the positive film. The magnitude of these distortions can be illustrated by selecting a test object of known dimensions, photographing it, and following the dimensional changes in the photographic image of the object throughout the life of the film. A suitable object may be a test target, as illustrated in Fig. 1, constructed on a dimensionally stable material such as glass. The target is 1.378 in. (35 mm) wide and of any convenient height. It consists of 4 fine lines *A*, *B*, *C*, and *D*. For convenience, line *A* is located 0.2000 in. from edge *O*, and line *B* is located 1.0000 in. from edge *O*. Lines *C* and *D* are 0.5000 in. apart. The image of this target is now transferred to a piece of 35-mm negative film by contact printing, perfect alignment of target and film at edge *O* being maintained when the exposure is made. There has now been produced on the 35-mm film a latent image whose dimensions are identical with those of the test target. The film is then processed.

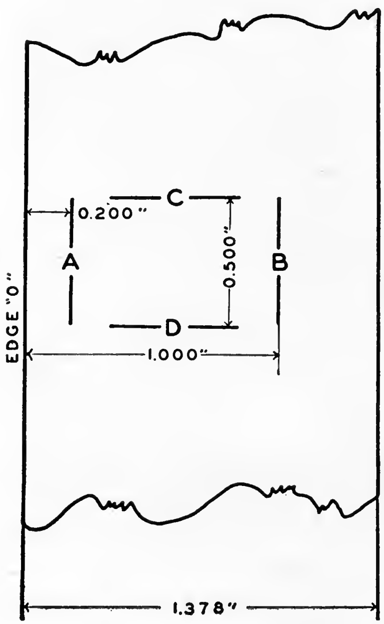


FIG. 1. Test target on glass for image distortion study.

Dimensional Changes in the Negative Film.—It will be found that the dimensions of the developed image on the film do not coincide exactly with those of the target. If care is taken to bring the negative film to equilibrium with air at the same relative humidity after processing as that of the air with which it was in equilibrium at the time of exposure, any dimensional changes will be caused solely by processing. The permanent processing shrinkage of Eastman motion picture negative film (nitrate base) is of the order of 0.10 per cent in length and 0.15 per cent in width. (For comparable shrinkages of Eastman motion picture negative film, safety base, see "The Physical Properties and Dimensional Behavior of Motion Picture Film" Table 4.[1]) Therefore, upon measurement of the image lines after processing, it will be found that line *A* has moved 0.0003 in. toward edge *O* from its original position, and that line *B* has moved 0.0015 in. toward edge *O*. Lines *C* and *D* are now 0.4995 in. apart.

Ordinarily, it is not necessary to maintain the processed negative in equilibrium with air at the same relative humidity as that with which it was in equilibrium at the time of printing. However, in the special cases noted, the changes in dimensions which accompany changes in moisture content of the negative become an important factor. It may be assumed that most negative raw stock, when removed from the container, is in equilibrium with air at about 60 per cent relative humidity. If the negative, after processing, is stored in a dry place, there will be a further shrinkage of the temporary or reversible type caused by loss of moisture. Thus, if the negative were stored in a vault in which the relative humidity of the air averaged 20 per cent, there would be a contraction of about 0.20 per cent lengthwise and 0.25 per cent widthwise owing to the loss of moisture. These dimensional changes are in addition to the permanent shrinkage caused by development. Consequently, line *A* has now moved a total of 0.0008 in. toward edge *O*, line *B* has moved a total of 0.004 in. toward edge *O*, and lines *C* and *D* are 0.4985 in. apart.

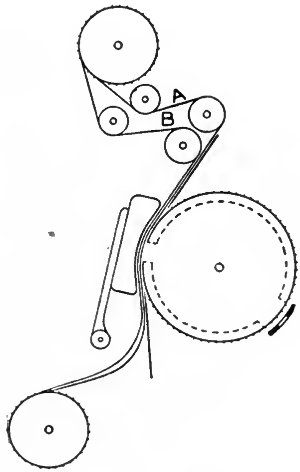


FIG. 2. Film paths on a typical continuous Printer: *A*—Path of the negative; *B*—Path of the positive.

This is not all. There will be further permanent shrinkage on storage, owing to a gradual loss of traces of solvent or plasticizer from the processed negative. The shrinkage of Eastman nitrate motion picture negative film resulting from loss of material upon storage under normal conditions for one year is approximately 0.3 per cent lengthwise and 0.4 per cent widthwise. Consequently, after one year, under normal keeping conditions, the following shrinkages of the negative may have taken place:

	Lengthwise, per cent	Widthwise, per cent
Processing shrinkage	0.10	0.15
Humidity change contraction	0.20	0.25
Keeping shrinkage (1 year)	0.30	0.40
	0.60	0.80

The positions of lines *A* and *B* will be 0.0016 in. and 0.008 in., respectively, closer to edge *O* than in their original positions, and lines *C* and *D* will be 0.4970 in. apart.

Ordinarily, distortions of this magnitude have little or no significance when the negatives are used for normal printing. In special cases where distortions of this amount are objectionable, the dimensional changes accompanying variations in moisture content can be kept at a minimum by reconditioning the negative to 60 per cent relative humidity. The shrinkage during keeping can be minimized by storing the negatives in sealed containers at about 50–60 F and at 40–50 per cent relative humidity, when not in use.

Dimensional Changes in the Positive Film.—The positive print, after exposure to the negative, is subject to the same general dimensional changes which have been described in the case of the negative. That is, there will be a shrinkage upon development, dimensional changes produced by variations in the moisture content, and shrinkage upon storage owing to the loss of solvent or plasticizer. It would be possible, therefore, in the very unusual case in which all dimensional changes in the negative at the time of printing were as great as possible and all additive, and in which subsequent to printing the dimensional changes of the positive were as great as possible and all additive, to have displacements of certain lines in the print of the order of 0.02 in. from those of the original subject.

Image Distortions Produced in Contact Printing.—In contact printing, the negative and positive are brought together, emulsion layer to emulsion layer, and the exposure is made. At first thought, one would expect that an exact reproduction of the negative image would in all cases be recorded on the positive. In a step printer, in which each frame of the negative is held in contact with the positive film in a flat plane when the exposure is made, this is substantially true. In the case of a continuous printer, in which the exposure is made after the negative and positive are brought in contact on the curved surface of a drum, the image of the negative is not transferred unchanged in all respects to the positive. In Fig. 2, which illustrates a portion of a continuous printer, it may be seen that the negative film travels in a circular path which is shorter than that of the positive. Thus, for a drum of 1.887-in. radius, as on the standard Bell and Howell Model *D* printer, and assuming that the neutral axis

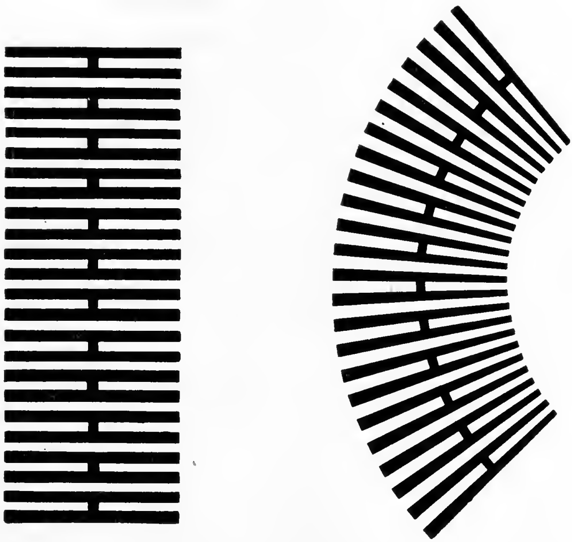


FIG. 3. Compression and extension effect on bending an elastic material.

of the film is at the center, the path of the negative is 0.317 per cent shorter than that of the positive. If the perforation pitch of the positive is equal to that of the negative, the positive film must gain its greater distance of travel by slipping past the negative film during exposure to the extent of 0.317 per cent. In practice, it is usually found that the positive film is unshrunk and that the negative, because of processing and the time interval which exists between processing and printing, has shrunk nearly 0.2–0.3 per cent. When such is the case, printing on a continuous printer is quite satisfactory. The pitch of the negative must be approximately 0.3 per cent less than that of the positive, or the picture will appear slightly unsteady and the sound will be slightly distorted.

These considerations in regard to continuous printing are quite obvious and certainly well understood. There is, however, another effect which takes place when the exposure is made while the negative and positive are in contact on a curved surface which is not so generally appreciated. When any elastic material is bent, the concave side is compressed, and the convex side is stretched (Fig. 3). Therefore, on a continuous printer, the emulsion side of the positive film is compressed, and the emulsion side of the negative is stretched at the instant of exposure. Obviously, this effect will make it impossible to reproduce exactly longitudinal dimensions of the negative onto the positive by this manner of printing. Assuming again that the neutral axis of the film lies at its center, the positive emulsion surface has been compressed longitudinally 0.317/2 or 0.158 per cent, and the negative emulsion surface has been stretched 0.158 per cent at the instant of exposure. When the positive film returns to its normal or flat position, the emulsion surface will expand 0.158 per cent, giving a total longitudinal increase in dimensions of 0.317 per cent. This degree of distortion is so small as to be inconsequential in the case of ordinary usage. It is only in connection with the special fields noted that it is of significance.

Up to this point we have considered the distortion of the image on the film itself. In certain cases this image will be projected either onto another film or onto a screen. When this is done, distortion of an entirely different nature may be encountered. It has been shown in a previous paper[2] that the heat of the projector lamp frequently causes the film to assume a curved shape during the instant the film is in the aperture of the projector. This curvature of the film produces distortion in the projected image. In the case of theater projection, these distortions are seldom noticeable. In special cases, where little or no distortion of the projected image is permissible, it will be necessary to reduce the heat intensity at the film surface with heat-absorbing media to the point at which these image distortions disappear.

Film Defects Associated with Insufficient Drying.—Although a great many studies have been made of most of the steps in film processing, very little has been published on the subject of the drying of film. There are great differences of opinion in regard to the best conditions for drying. Most of the steps in the laboratory handling of film from printing to screening are controlled by a practical evaluation of the results obtained. For instance, if too much light is used in printing, the resulting print appears too dark on the screen and the necessary correction is made in the case of succeeding prints. If the processing solutions are not correct, a print of too high or too low a degree of contrast may result. An adjustment is, therefore, made in the time of processing or in the solutions. However, in the case of

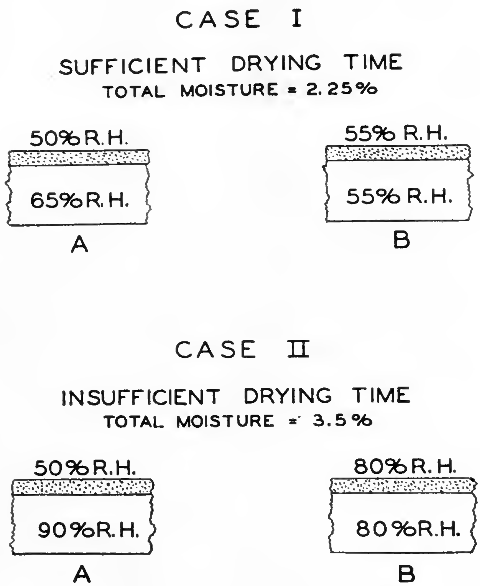


FIG. 4. Effect of drying time on moisture distribution in motion picture positive film: *A*—Relative humidity with which each layer is in equilibrium at end of drying period; *B*—Relative humidity with which each layer is in equilibrium after standing in roll form.

the drying of film, a step which affects the appearance and operation of the print for the remainder of its useful life, there is no simple guide for the processing superintendent. The only guide he has, the appearance of the film, may be deceiving. Admittedly, the operator can see when the film is "sensibly dry," but this observation applies only to the emulsion layer. It tells him nothing concerning the dryness of the base. It is possible, when drying fine-grain emulsion films at a low dry-bulb temperature and low relative humidity, to reel the film with the emulsion layer practically in equilibrium with the air of the drying cabinet, but with the base only in partial equilibrium with the air of the drying cabinet. This results from the fact, as Calhoun has pointed out, that the emulsion layer reaches equilibrium with air at a much more rapid rate than does the base. When films dried in this manner are reeled, moisture is transferred from the base to the emulsion until the 2 layers are in a state of moisture equilibrium. This effect is illustrated in Fig. 4. In these examples, samples of film were suspended in air at 50 per cent RH (relative humidity) for 2 different periods; the first was allowed to stay for a considerable time, and the second was removed as soon as it appeared "sensibly dry."

The first sample in Fig. 4 contained 2.25 per cent moisture by weight, and if allowed to equilibrate without loss or gain would have been in equilibrium with air at 55 per cent RH. Because the emulsion dries so rapidly, however, at the time the sample was removed for analysis the emulsion had gone substantially all the way toward equilibrium with the air at 50 per cent RH. Yet the base with its much slower drying rate had gone only 70 per cent of the way, and still contained enough water to be in equilibrium with air at 65 per cent RH. It is only after several hours' equilibration (wound in a roll, for example) that both emulsion and base would attain the overall equilibrium of 55 per cent RH.

The second sample, which was removed as soon as it showed the change in the direction of curl associated with "sensible dryness," contained 3.5 per cent moisture by weight, sufficient so that if allowed to equilibrate without further loss or gain, it would have been in equilibrium with air at 80 per cent RH. Nevertheless, the emulsion, at the time the sample was taken, had, as before, dried almost completely to equilibrium with air at 50 per cent RH. Only in the base was the short drying time apparent, for here the base had had the opportunity to go only 20 per cent of the way toward equilibrium with air at 50 per cent RH. It was as if a strip of emulsion at 50 per cent had been cemented to a strip of base at 90 per cent; the resulting film on equilibration of base with emulsion eventually reaches equilibrium with air at 80 per cent RH.

Even though, at the time the samples were taken, these 2 films looked and felt equally satisfactory, it is now apparent that only the first strip was sufficiently dried. The second strip with its high moisture content is subject to many defects directly caused by the moisture still present at the time of reeling. Defects often found on films dried in this manner are:

(*a*) Tackiness of the emulsion, causing sticking in the projector gates,

(*b*) High positive curl. This is especially true if the relative humidity of the drying cabinet air is very low and the time of drying very short. Film with high curl will, when wound into rolls, frequently show "spokiness" or, in the case of safety film, bad twist,

(*c*) Buckle, caused by the edges of the film drying more rapidly than the center and thereby becoming shorter. This distortion will frequently cause the picture to appear out of focus momentarily,

(*d*) Thermal "in-and-out" of focus. This is a phenomenon associated generally with the use of high-intensity lamps. It is aggravated by a high moisture content in the film.

These film defects have been described previously.[3]

Acknowledgment.—The writer wishes to express his sincere appreciation to Dr. E. K. Carver for his many helpful suggestions and for continued guidance in the preparation of the paper, and to the various members of the film testing departments of the Eastman Kodak Company for their contributions.

REFERENCES

[1] CALHOUN, J. M.: "The Physical Properties and Dimensional Behavior of Motion Picture Film," *J. Soc. Mot. Pict. Eng.*, **43**, 4 (Oct., 1944), p. 227.

[2] 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.*, **41**, 1 (July, 1943), p. 69.

[3] CARVER, E. K., TALBOT, R. H., AND LOOMIS, H. A.: "Film Distortions and Their Effect upon Projection Quality," *J. Soc. Mot. Pict. Eng.*, **41**, 1 (July, 1943), p. 88.

PROBLEMS OF THEATER TELEVISION PROJECTION EQUIPMENT*

A. H. ROSENTHAL**

Summary.—*Some of the more important problems of theater television projection technique and equipment are discussed. The importance of the two principles of optical storage and light modulation for overcoming certain limitations is stressed, and some Scophony developments are described in which these principles are utilized.*

It is indeed a great honor for me to discuss here before the Society of Motion Picture Engineers some technical aspects of television which are likely to become of great importance to the motion picture industry.

I was somewhat hesitant to give this talk because for various and obvious reasons I cannot enter into many technical details and current developments, but I realized that there were many problems of large screen television projection of a general nature. I intend to discuss some of the important problems and their solutions with particular reference to methods developed by Scophony, mainly before the war and perfected since.

Let us therefore survey some of the basic requirements for theater television projection, and then discuss some principal limitations and technical approaches to overcome those limitations.

Let us assume quite generally some sort of projection equipment for television, or also for motion pictures or lantern slides, consisting substantially of an image screen surface and an optical projection system which forms a magnified image of this surface on the theater screen. The observers of this theater screen are greatly interested in the following factors:

(*a*) Picture or screen size,
(*b*) Picture brightness,
(*c*) Definition or resolution of details.

* Presented Mar. 21, 1945, at a meeting of the Atlantic Coast Section of the Society.

** Director of Research and Development, Scophony Corporation of America, New York.

Further factors of interest include contrast, the ability of the system to reproduce fast movements, freedom from flicker, color hue of the picture, *etc.*

We may best realize the difficulties which have to be overcome in television projection by comparing it with motion picture projection technique. This is the more important since the public will approve only of large screen television if the pictures supplied thereby will stand comparison with the motion picture projections with which they are familiar.

In motion picture projection, similar to lantern slide projection, a picture of varying transparency or opacity on a transparent carrier is illuminated by means of a condenser system with the light of a standard light source, which may be an incandescent or an arc lamp, and then projected by an optical imaging system onto the theater screen. Actually, at each element of the theater screen the light originating in the standard light source is modulated in accordance with the local elemental opacity values of the film or slide. The projection occurs simultaneously for all elements of the picture, and in the case of motion pictures for a substantial part of the duration of one frame.

We shall see that the just-mentioned two facts, namely, the modulation of the light of a standard light source by the elements of the film picture and the simultaneous projection of all these elements to the screen, which are so naturally accomplished in motion picture projection, are not at all a priori evident in television projection technique. However, any television system which intends to satisfy the public by presenting pictures comparable to motion pictures must necessarily aim at these two features of light modulation and of simultaneous projection of as many elements as possible.

From the method of building up a television picture, it is evident that one cannot offhand expect a simultaneous action of all or even of many picture elements. A television picture is built up by the scanning process, *i. e.*, both at the transmitter and the receiver elemental portions of the picture area are successively active starting, for instance, from the upper left corner, elemental portions are swept in a horizontal line to the upper right corner. Then jumping back to the left border of the picture one horizontal line lower is scanned, and so on until the elemental scanning spot arrives at the lower right corner, which completes one frame, and after which it jumps back to the upper left corner. With a picture of the present standard of 525 horizontal lines, repeated 30 times per sec, the time available for one element to be scanned is less than one five-millionth of a second. It was soon realized at the transmitter end that it would be necessary to make each picture element active for a considerably longer time period. This was accomplished by introduction of electrical picture storage, as developed by Dr. Zworykin in the Iconoscope, in which the light impressions and the photoelectric elemental charges are stored for a great part of the frame period.

As long as one is satisfied at the receiver end with relatively small pictures, measuring in inches rather than in feet, one can get around these storage considerations, and build up pictures in which at any time substantially only one element is active. As soon, however, as the requirements of size and brightness become less modest, it is necessary to consider means of having as many elements as possible simultaneously illuminated at the picture screen. This can be achieved by

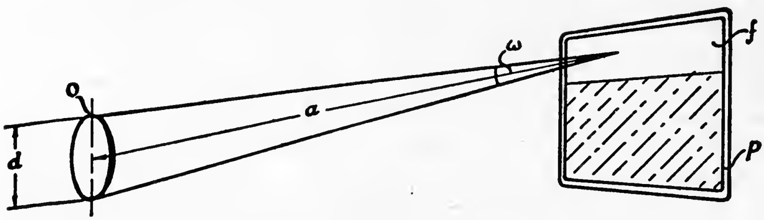


Fig. 1.

making use of optical storage at the receiver end and deriving therefrom benefits as important as those derived from the electrical picture storage at the transmitter end.

The term "optical storage" denotes the fact that though the optical changes at each picture element are created by the scanning process during the above-mentioned short time, each picture element retains its optical qualities for a time far in excess of this short elemental scanning period, in other words, "stores" the optical impressions. Thus, if, for instance, a given element retains its light value for a duration corresponding to the time in which 200 elements are successively scanned, this means that 200 elements are active simultaneously at any time. If any element retains its impressions for the whole frame period, it means that all elements of the picture are active simultaneously; this corresponds to the ideal case of motion picture projection.

Fig. 1 illustrates these conditions showing a projection system *O* throwing a picture on a picture screen P. In a slide or film projector all elements of the screen, or its whole surface would be simultaneously illuminated. In a television system without storage only one picture element of an elemental area representing about one two-hundred thousandths of the total screen area would be active at any time. In a television system employing a certain amount of optical storage, a certain part f of the screen area would be illuminated simultaneously, the remainder being dark. During the scanning of the picture this active area f will be at different parts of the screen, but the system may be characterized by the ratio of the active area f to the whole screen area F, called the storage ratio r of the system. This thus defined storage ratio would be practically zero for a system without storage, in which only an elemental area is active, and it would be practically one for a system in which all picture elements are active simultaneously.

Returning now to the two most important of the above-mentioned factors of interest, namely, picture size and brightness, we obtain the following expressions:

$$E = cr\frac{d}{a}I$$

$$E = c'n\frac{d}{aF}I$$

$$r = \frac{f}{F}$$

in which E is the screen illumination, I is the brilliance of the light source, a is the projection distance, d is the effective diameter of the projecting exit pupil, n is the number of simultaneously active picture elements, and c and c' are constants which include losses by absorption, screen scattering factor, shutter action, "fly-back" time in the case of television, *etc.*

From these simple expressions one can see that the screen brightness is proportional to the number n of simultaneously active picture elements, or, in other words, to the storage ratio r of the television system.

Some idea of the actual values obtainable is given in Table 1. These values result from the above formulas by inserting therein an average screen brightness of 10 ft-L, using for projection an arc lamp of a brilliance of, say, 150,000 candles per sq in., a projection system with an effective exit pupil d of 2 in., and assuming a total loss factor c of 50 per cent.

TABLE 1

n Simultaneous Elements	r Storage Ratio	a/d Projection Ratio	a_{max} Maximum Projection Distance, for $d = 2$ in.
1	1/200,000	4	8 in.
300	1/700	70	12 ft
100,000	1/2	1300	200 ft
200,000	1	1800	300 ft

The first column shows the number of simultaneously active elements (with a 525-line standard), the second column the corresponding storage ratio, the third column the projection ratio, that is, projection distance a to projection opening d, and the fourth column shows the maximum projection distances a_{max} allowable in order to obtain the above screen illumination of 10 ft-L. This table, the values of which are based on average motion picture theater conditions, shows that for a television system in which only one element is optically active at a time, that is, a system with no storage, a very short projection distance of less than one foot results. It is obvious that even with a projection system of extreme wide-angle type only a picture size of the order of the projection distance could be obtained, that is, of less than one-foot width.

Thus the values show the impossibility of obtaining even with a high-intensity arc lamp a picture of reasonable size and brightness with a television projection system with no storage.

The second row, which represents a television system in which 300 elements are simultaneously active, gives a maximum projection distance of 12 ft, and thus could provide a picture of average theater screen brightness and of a linear size of the order of 12 ft. Naturally, the assumption of an effective opening of 2 in. was made with a view to motion picture projection systems, and the conditions for a television system of limited storage will look more favorable if a projection system with a larger aperture is used.

But it is obvious that one soon arrives at a practical limit, even with special projection systems. For instance, in the first case of a television system without storage, in order to obtain a theater picture of about 20-ft width one would require a projection system of an effective aperture of at least 60 in. diameter, which seems to be somewhat on the impractical side.

The next 2 rows show corresponding values for storage ratios of one-half and of one. Thus with a television system in which half of the picture elements are simultaneously active, one would obtain a maximum projection distance of about 200 ft, which of course would permit a picture of very large size, sufficient even for the largest theater screens such as, for instance, in drive-in theaters. With a projection distance of 100 ft either the effective diameter of the projection system could be reduced to about one inch, or with a 2-in. system a very large screen brightness of approximately 40 ft-L could be obtained.

These figures are only intended to illustrate the great importance of optical storage in television projection systems, that is, of designing the system in such a way that as many as possible of the picture elements are simultaneously illuminated on the screen. Only by a high optical storage can a television picture of satisfactory size and brightness be produced with economical optical means.

I have just tried to illuminate the great advantages of a television projection system with a high optical storage ratio by comparing it with a system with no storage. Similarly, we can appreciate the advantages of the principle of light modulation by discussing the limitations of television projection systems in which no modulation of the light of a standard light source is used.

The most prominent, and probably the only practical example of such a television system using no standard light source and modulating the light thereof, is based on the fluorescent screen cathode-ray tube. Here the picture is produced on a fluorescent screen by scanning the screen with an intensity modulated cathode-ray beam. The electric energy of this modulated cathode-ray beam when impinging the fluorescent material is converted, at least in part, into light energy, and a self-luminescent picture thus created on the fluorescent screen. The image can be observed directly if one is satisfied with picture sizes that can be accommodated on the end face of a cathode-ray tube, and which for practical reasons are limited to the order of 10 in. in width.

When larger pictures are desired, it is necessary to project this self-luminescent picture by an optical system onto the large viewing screen. The principal disadvantages of this method become apparent if one aims at pictures of theater size and theater brightness. Size and brightness of the picture determine the total light energy which must issue from the exit pupil of the projection system. Whereas in light modulating projection systems, whether for television or for film projection, this light energy is derived from a strong standard light source and is quite independent of the modulation and the television signals themselves; in the case of a self-luminescent picture, the light energy at any moment is determined by the modulated electric energy of the cathode-ray beam which is converted into light energy at the fluorescent screen. Thus in a fluorescent cathode-ray tube the total light output represents the converted modulated power of the cathode-ray beam whereby the beam modulation is produced by the amplified television signals. Further, this light energy is being created at only one picture element at a time.

With a 525-line picture, the cathode-ray beam energy which is far in excess of the total light energy obtainable must be concentrated in a spot of $^{1}/_{200,000}$ of the area of the fluorescent screen which, in the case of a 10-in. screen, amounts to about one-tenth of a square millimeter.

Since the light output of a fluorescent screen is only up to a certain beam current density proportional to the beam current, and saturation occurs already at a current density considerably below that required for satisfactory brightness and definition, the total light output can be practically increased only by increasing the spot size or, in other words, by sacrificing picture definition.

Further, a fluorescent screen represents a rather perfectly diffusing light source. An optical system with an aperture $f/2$ would gather only about 6 per cent of the light flux emitted in a forward direction by an axial element of the fluorescent screen. In order to gather an appreciable amount of the limited light flux of the self-luminescent picture, special optical systems of very high aperture, such as the Schmidt system, have to be used. But even then, with the extremely high voltages of about 70,000 v necessary with these projection cathode-ray tubes, it appears doubtful whether a practical theater television projection system giving pictures of satisfactory size, brightness, and definition will ultimately be based on the self-luminescent fluorescent cathode-ray tube method.

A projection method in which the light energy is not derived from converted signal modulated power, but from a standard light source, and in which the signals serve only to modulate in the way of a relay or valve the intensity of this standard light source, is inherently free from these limitations. Conventional optical systems can be used to concentrate the light from the standard light source upon the light modulating device, and to project therefrom a picture on the screen by means of directed light similar to film projection without a great deal of loss, as is the case of the perfectly diffusing self-luminescent fluorescent picture.

Further, provided a sufficient amount of optical storage and light flux directed to the viewing screen is available in the system, a practically complete independence of picture brightness and definition results, the brightness being determined by the light source and optical storage, and the definition being determined independently by characteristics of the light valve. I shall discuss the light valve later in connection with typical examples for light modulating systems.

Summarizing, we have seen the increasing importance of the two principles of optical storage and of light modulation as we approach conditions of theater television projection.

We have been interested in theater television because of our close commercial connections with motion picture theater interests.

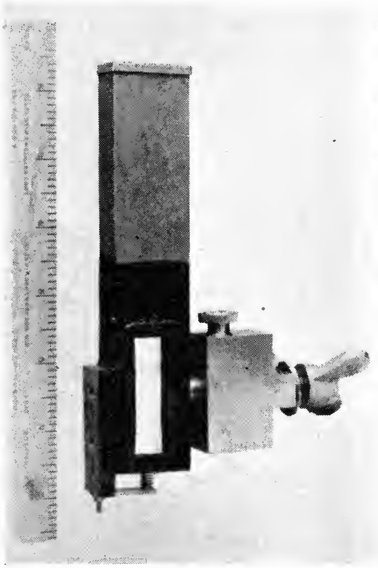


FIG. 2. Supersonic light modulator cell.

Rather than forcing improvements on existing systems which inherently appear to be not so well adapted to the large screen problems, and overstraining their possibilities, we aimed at developing systems which would be free from such limitations and would therefore offer greater scope for any possible increased future requirements as to picture standards. Therefore the efforts of the research and development work were directed toward systems employing the principles of storage and light modulation.

By way of example, I should like to describe briefly the following 2 systems which, though based on different physical phenomena, both employ these two principles.

The first is the Supersonic system. It is based on the diffraction of light by supersonic waves in a liquid. The liquid is contained in the supersonic light modulator cell (Fig. 2) which forms an essential part of this system. Supersonic traveling waves are created in the liquid by a piezoelectric quartz plate in contact therewith and excited by an electric oscillator to supersonic resonance vibrations of a frequency between 10 and 20 megacycles. The electric oscillations are amplitude-modulated by the television signals. Thereby supersonic waves of varying intensity are propagated from the crystal to travel in the liquid column. Light beams from a standard light source are sent through this liquid column. Depending upon the local amplitude of these waves, more or less light is diffracted from its path be-

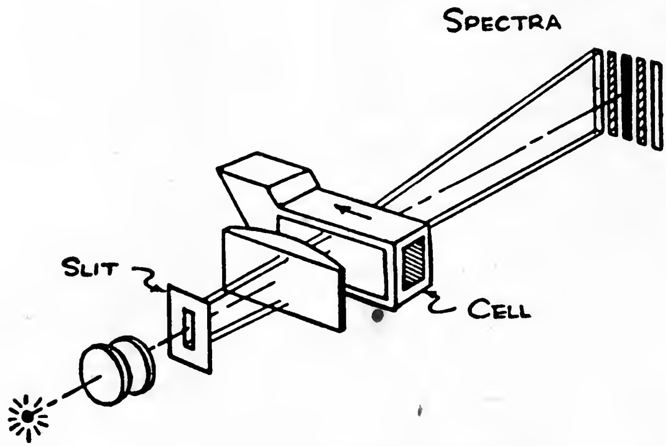


Fig. 3.

cause supersonic waves represent periodic compressions and rarefactions of the liquid, resulting in periodic variations of its refractive index. These optical variations, which are arranged along the liquid column, act as a variable diffraction grating upon the light beams. This can be seen from Fig. 3. Light is concentrated by condenser lenses upon a slit and is made parallel by a further lens to traverse the supersonic cell. A diffraction spectrum results in an image plane if supersonic waves are excited in the cell.

Fig. 4 shows that the diffraction spectra are produced in an image plane of the illuminating slit. A bar or stop is arranged in this plane so that it will just obscure this image if no supersonic waves are present. Thus no light will pass this stop. If, however, supersonic waves are excited in the cell, light is diffracted from its normal path and will therefore pass the stop in proportion to the intensity of the supersonic waves, or of the television signals. Thus the device acts as a light modulator.

It is very interesting and useful that the supersonic waves excited by the signal modulation carry this modulation along in their propagation through the liquid. It is as if a blank film would pass with a certain velocity along the crystal at which point modulations are impressed on the film which are carried along by it. Thus the various successive parts of the film, or of the liquid column, will carry modulations corresponding to successive picture elements of the television picture. Depending upon the length of the liquid column, a consider-

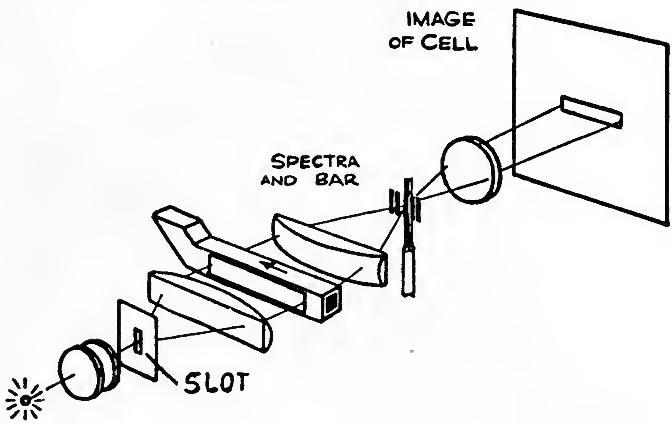


FIG. 4.

able number of successive picture elements are thus impressed upon this column at any moment and can be utilized. The supersonic waves travel with the sound velocity of the liquid, which is of the order of three-quarters of a mile per second. Since a picture element of a 525-line picture corresponds to about one five-millionths of a second, the length of the liquid column carrying the modulation of one element corresponds to about one-fifth of a millimeter in the cell. Thus an active liquid column of 2 in. would accommodate about 250 picture elements. Since a column of this or even a greater length is utilized, it can be seen that the supersonic light modulator permits a storage or simultaneous representation of several hundred picture elements.

The liquid column, itself, with its impressed picture modulations is imaged upon the viewing screen, and represents thereon a considerable part of a picture line. Since these modulations, however, move in that column with sound velocity, the picture elements also move in the line image represented on the screen. It is necessary to stop this movement by introducing an opposite compensating movement. That is accomplished by a rotating mirror polygon called the high-speed scanner, which immobilizes the elements on the screen. Fig. 5 shows this scanner introduced behind the bar.

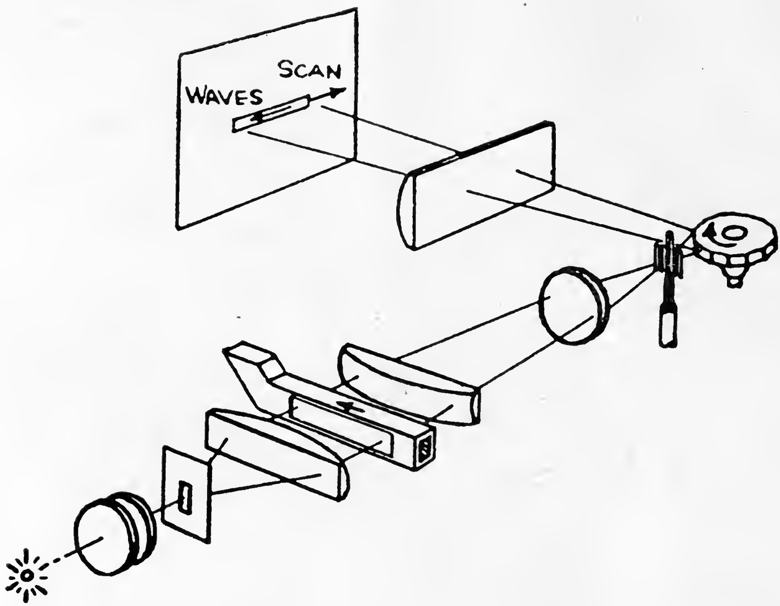


FIG. 5.

It is still necessary to introduce a deflection perpendicular to the lines in order to arrange the consecutive picture lines spaced properly in a 2-dimensional picture. This is accomplished by a second rotating mirror polygon called the low-speed scanner. Fig. 6 shows the complete principal arrangement. This figure also shows several cylindrical lenses which are quite important to realize in a practical and economical way the advantages of the system, and which make possible a great reduction in the size of the high-speed scanner which has to rotate with a very high speed. The rotation of the scanners is controlled by the synchronizing signals of the television system, and very effective motors have been developed for this purpose. The system thus employs the essential principles of light modulation and optical storage. For theater purposes, a standard motion picture arc lamp is used as light source, and Fig. 7 shows a complete projector for theater use, in which the arc lamp can be recognized.

Television pictures of theater size have been shown regularly and commercially in London theaters and also experimentally in a New York theater before the war. To give an impression of the great public interest shown, and to be expected for theater television, Fig. 8

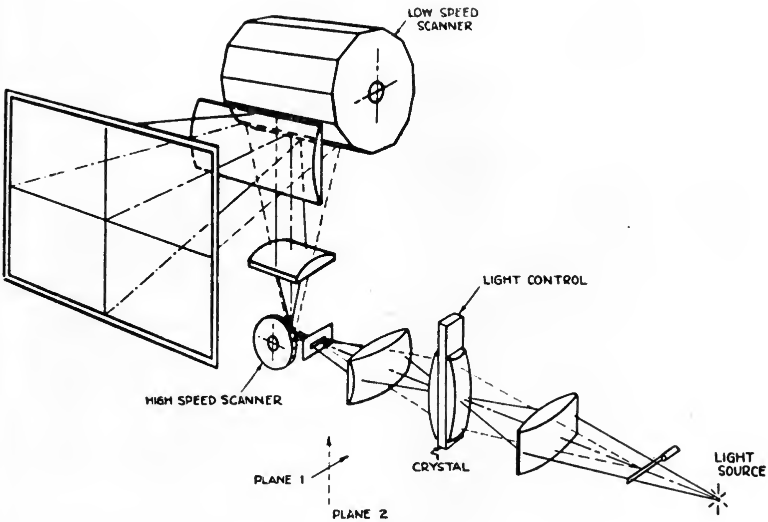


FIG. 6.

shows a crowd of people in front of one of the London theaters in which this equipment was used.

The next example concerns another development based on quite different physical principles.

I had mentioned in the beginning that in terms of television technique, motion picture or slide projection can be regarded as a light modulation process with all elemental portions simultaneously active, thus a light modulation system with full storage.

A television system which would most closely resemble motion picture or slide projection technique would contain a small screen of the size of a lantern slide, for instance, the elemental transparencies of which could be controlled in a simple way by the television signals. Retaining the local elemental transparencies for a considerable part of the frame period would result in a high storage ratio. Such a screen of variable transparency could then be projected similar to a lantern slide or film, using a standard light source.

A method using this principle is the Skiatron. It consists substantially of a special type cathode-ray tube in which the self-luminescent fluorescent screen is replaced by a screen of a material exhibiting the property of "electron opacity," that is, the normally transparent material can be rendered more or less opaque by the electrons of an impinging cathode-ray beam. This interesting electron opacity effect which occurs in various ionic crystal materials, for instance of the alkali-halide class, has been for many years a scientific curiosity, until the writer realized that it happens to have very desirable qualities for television and other applications. This was confirmed by our experimental and theoretical investigations.

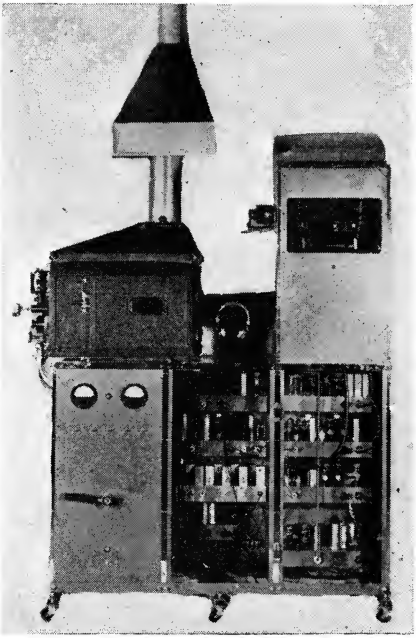


FIG. 7. Scophony theater television projector.

The physical nature of the electron opacity is quite complicated and by no means completely explored as yet, similar to the nature of fluorescence to which it is related. But we can get some idea of what happens with a simplified model as shown in Fig. 9.

Such an ionic crystal, for instance, potassium chloride, consists of a lattice of alternately arranged positive potassium ions and negative chlorine ions. Suppose that a layer of such a crystal is subjected to an electric field as indicated. The crystal normally is transparent to visible light. If, now, an electron from a cathode-ray beam enters the crystal lattice, it will be attracted by the nearest positive potassium ion, and will form with it some sort of loosely bound potassium atom which now shows an absorption in the visible spectral range, and is therefore called a color center.

The binding forces between the electron and the ion are rather weak, and after a short time the electron is again split from its ion by the thermal vibration forces of the crystal lattice. The electron moves on in the electric field until it is again captured by another positive potassium ion, forming again a color center a little nearer to the anode of the electric field. This process is repeated many times, the electron being, so to say, made visible temporarily when it is

FIG. 8.

bound as a color center to lattice ions. Exchanging from ion to ion it finally approaches the anode side of the electric field and leaves the crystal.

Figs. 10 to 15 show these opacities in an ionic crystal. A small potassium bromide crystal in this experiment is held in a frame and at a suitable temperature, and a platinum point inserted at one side, while the opposite side has a flat metal electrode. When the platinum point is given a sufficiently negative potential with respect to the other electrode, electrons enter from the point into the crystal and are made visible in the manner described as an opaque cloud. The various photographs of this crystal were made at different times (Fig. 10 before applying the potential) and show how the opacity develops in the crystal. When the field is reversed (Figs. 14 and 15), the opacity cloud returns again toward its source and leaves the crystal clear. This experiment is somewhat different from the television application, but illustrates the nature of the electron opacity. Such experiments are useful to measure various factors of interest for the applications.

If a cathode-ray beam containing many electrons impinges for a certain time on a given area of such a crystal layer, a local opacity is created at that area, and this opacity, representing electrons, moves across the crystal layer and disappears after a given time leaving the

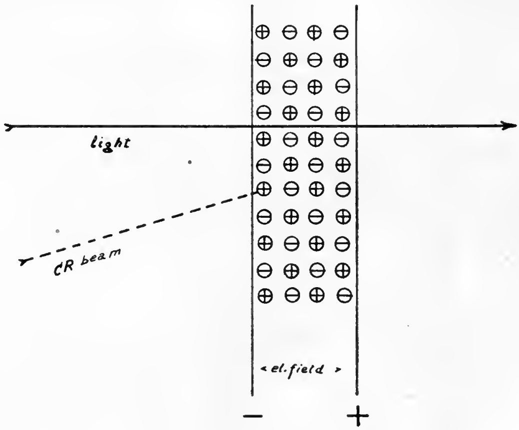


FIG. 9.

crystal layer clear. A closer investigation of this electron opacity phenomenon shows that the speed of movement and disappearance of the opacity depend upon various factors, such as the electric field, temperature, nature and thickness of the crystal material, and that it can be influenced within wide limits by various factors. Of greatest interest to our problem is the fact that these magnitudes are within ranges suitable for television projection.

Fig. 16 shows a schematic diagram of such a Skiatron projection arrangement in which you see the tube with its crystal screen in which the fugitive opacity image is created by scanning this screen with the signal modulated cathode-ray beam. This fugitive image consists of areas of variable opacity or transparency, quite similar to a film or lantern slide picture, and it can be projected in a similar way by a standard light source, condenser, and projection lens onto a projection screen through suitable windows in the tube wall. We have thus a simple shadow picture projection, which is the basis for the name Skiatron from the Greek word *skia* meaning shadow.

Generally speaking, any intelligence traced upon the electron opacity screen by a cathode-ray beam is represented thereon by temporary local changes in its optical properties, such as its transparency, its reflective power, its refractive index, *etc.* Therefore, these traces can be made visible in various ways by illuminating the screen (with various light sources, also daylight), apart from the just-described projection method, which is only one of the various applications embodied in the Skiatron patent group.

A high storage effect is inherent in this method by substantially retaining the opacity values unchanged over the frame period. A previously created opacity in a given area can be made to move across the crystal within the frame period, thus remaining substantially constant, and to disappear at the end of this period, when the scanning beam returns to the same area, inserting therein the electrons and creating the opacity for the next frame.

Fig. 17 shows a laboratory setup of the system in which can be recognized the tube, the condenser, and the projecting lens. The electron opacity screen is of microcrystalline structure.

Experiments in the course of developing this system, including television picture reception, have shown great promise that the above-mentioned ideal performance, which can be anticipated from the physical basis of these effects, should be fully realized by continued research dealing mainly with the electron opacity effects. It has been mentioned that these effects are physically related to fluorescence and phosphorescence, and contemplating the great improvements of fluorescent materials from a few years ago when they were first applied in television tubes, one can anticipate similar important developments of this scientifically related art which appears to be far more adapted to the problems of television projection.

Since the light output in the projected picture is derived from a standard light source and does not represent converted modulated power, and thus the amplified television signals are used only to modulate and not to generate the local light intensities, it is not necessary to sacrifice picture definition for picture brightness here. The definition is determined only by electron optical questions which are well solved in modern cathode-ray tube technique. Experiments

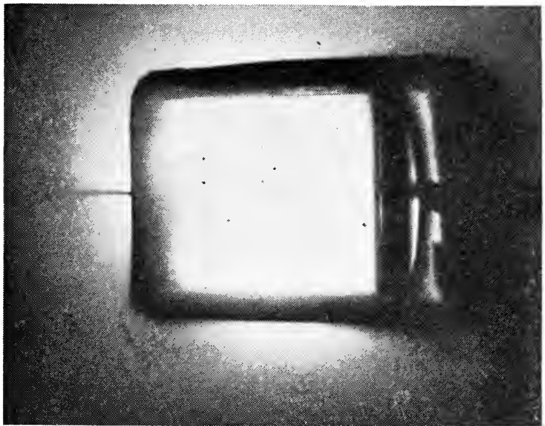


Fig. 10.

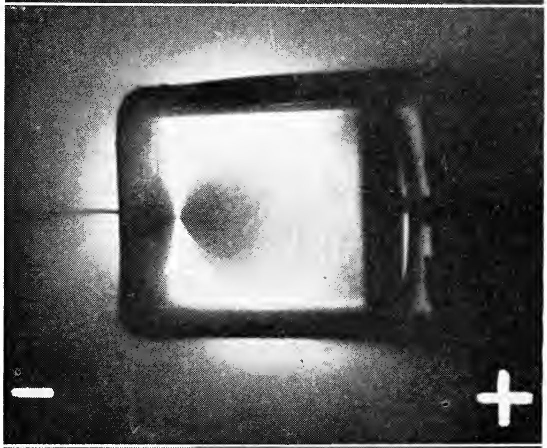


Fig. 11.

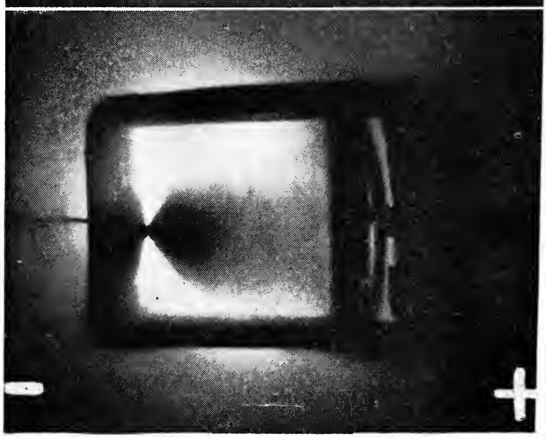


Fig. 12.

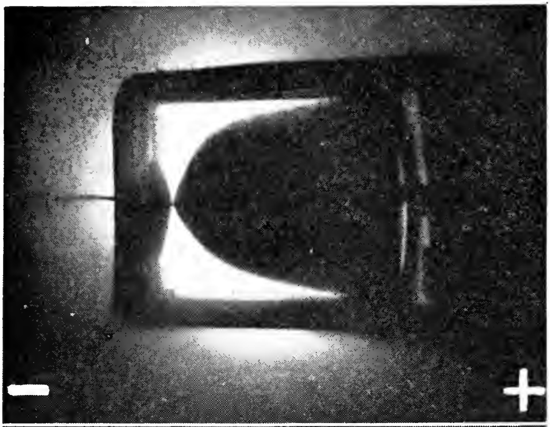


FIG. 13.

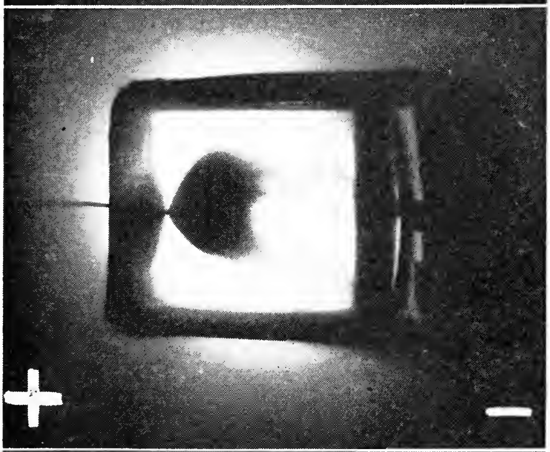


FIG. 14.

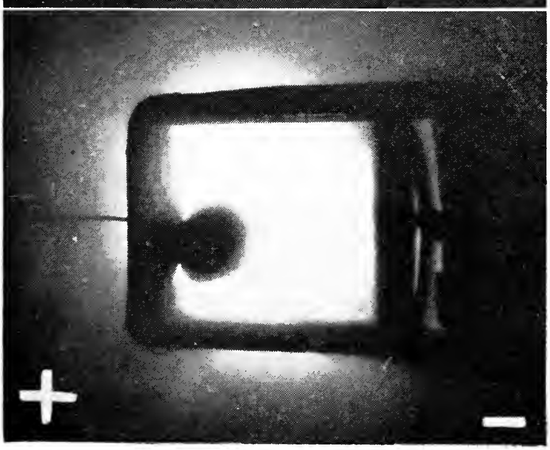


FIG. 15.

indicate that even a far greater number of lines than the present 525 can be used. Also the Supersonic system, as will be clear from previous description, is not limited to present definition standards.

The Skiatron represents a cathode-ray controlled light valve and thus a purely electronic system. It employs the principles of light modulation and high optical storage, and there is much reason to expect that this system may ultimately acquire great importance both for theater and home television.

The examples described above of theater television methods are in many respects similar to motion picture technique. There comes to

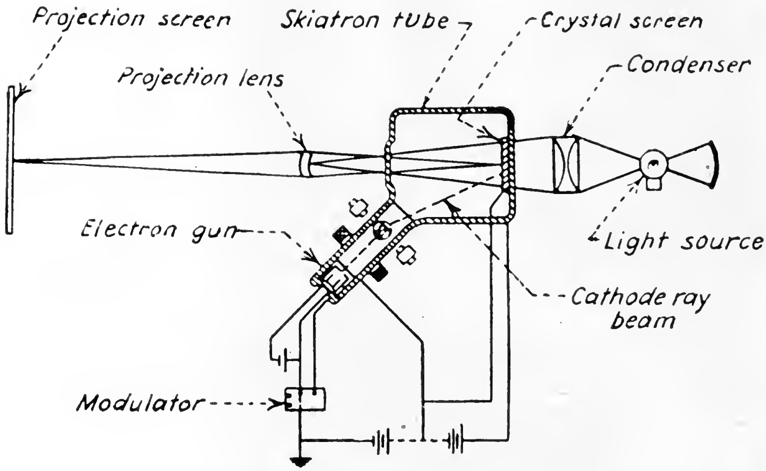


FIG. 16.

mind another theater television projection method, namely, the intermediate film process, in which television pictures produced on a cathode-ray tube screen are photographed on a motion picture film, and, after speedy processing of this film, projected through a motion picture projector. It is interesting to note that the Skiatron method, producing pictures of varying transparency, resembles in this respect the intermediate film process without, however, consuming film. There is even a deeper physical analogy between the two methods because the electron opacity effects are basically related to the photographic process.

Among the various embodiments of the Skiatron principle there is one in which the electron opacity pictures are created by the scanning and modulated cathode-ray beam on a movable, endless carrier, such as a film loop or disk carrying the ionic crystal material. At one position of this carrier the electron opacity image is impressed thereon, then the carrier traverses a projector in which the image is projected to the viewing screen, at a later position of the carrier the picture is extinguished, and then returning to the first position the carrier receives the opacity picture of the next frame.

May I briefly say a few words about color television projection? Small color television pictures were demonstrated both in this country

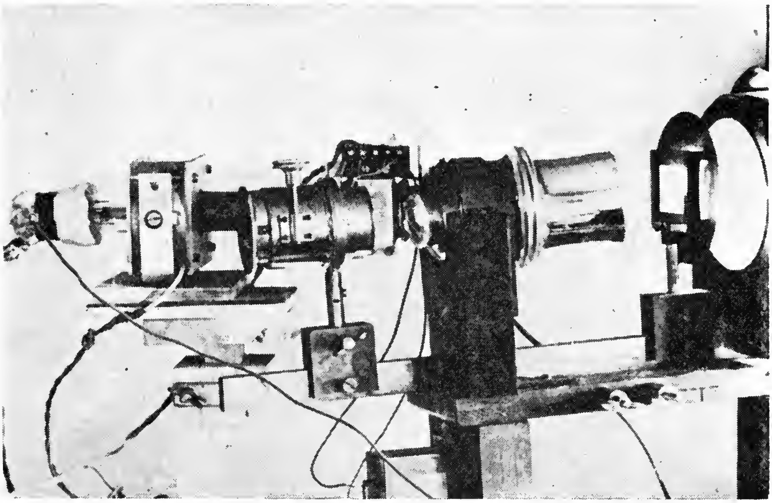


FIG. 17.

and in England before the war, by making use of a color filter disk rotating in front of the picture on a cathode-ray tube, and thus successively presenting to the eye of the observer partial color pictures. This disk rotating in front of the picture has to be quite big.

Such an additive successive color method can be easily applied to the Skiatron and Supersonic methods, and in this case the filter disk can be made quite small by inserting it near the optical imaging system where the whole light energy is restricted to a small cross section.

The Skiatron method can also provide a subtractive color television system. This is based on the fact that the color centers or opacities have different colors for different crystal materials. Projecting the light through 3 electron opacity screens S_1, S_2, S_3 of suitable materials, and creating on each of these screens an opacity picture corresponding to one partial picture of a 3-color system (thus of

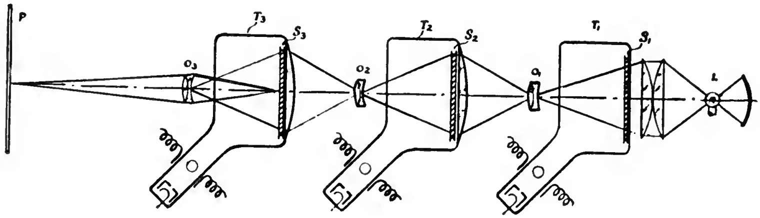


FIG. 18.

minus red, minus green, and minus blue colors), leads to a subtractive color television system. The principle of this is shown in Fig. 18, in which you see 3 Skiatron tubes T_1, T_2, T_3 through which light is pro-

FIG. 19.

jected from a standard light source L to a viewing screen P by lenses O_1, O_2, O_3, taking care that the partial pictures are projected in register. Two of the screens may also be combined in one tube.

From the experiences of color photography and color motion pictures, the far greater optical efficiency of a subtractive color projection process compared with an additive one is well known. Present color motion picture and photography processes are therefore based on subtractive methods, like Technicolor and Kodachrome. The same considerations apply to projection of color television, and it may be anticipated that here also a subtractive process of the kind described will finally be used.

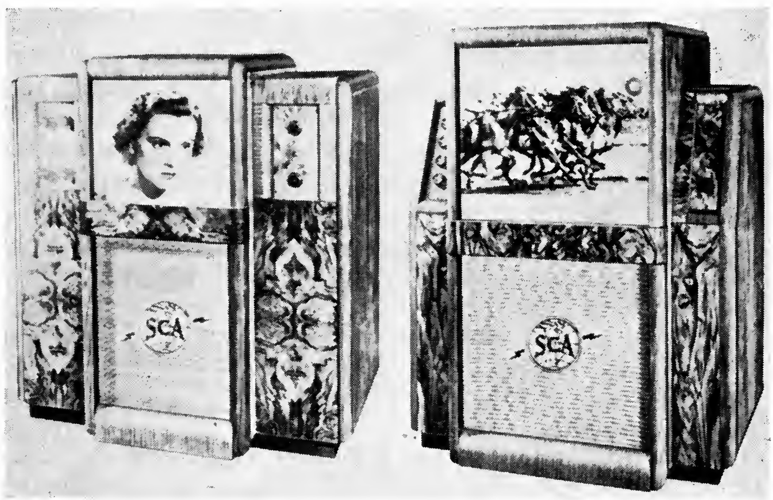


FIG. 20.

A further aspect of a full storage system, that is, of a continuous melting of successive picture frames, to which the Skiatron method lends itself, is the possibility of reducing the frame repetition frequency without causing undue flicker and impairing motions. With full storage this frequency could be reduced by about 50 per cent, therewith also similarly reducing the total frequency band width of the television signal spectrum. This should be very important in view of the discussions aiming at increasing the number of lines, particularly for theater television, ultimately to perhaps 1000, which would greatly increase the necessary frequency band.

I have tried to sketch some of the more important problems of theater television equipment, and to illustrate these problems, by way of example, by briefly describing the principles of some Scophony developments, rather than going into technical details. I may just mention that many far-reaching improvements have been and are being made on these methods beyond what has already been published previously.

Finally, though it is not within the scope of this talk which deals with theater television, it may be mentioned that the previously described methods based on light modulation and optical storage can be very successfully applied to smaller pictures, in which case the carbon arc is replaced by smaller light sources. To illustrate this, Fig. 19 shows a Scophony projector giving a picture of 4-ft width which has been designed for schools and lecture halls. Fig. 20 shows 2 models of Scophony home projection receivers giving pictures of 18 and 24 in., respectively.

When television is generally available to the public, public reaction will provide, as it has in radio, many new problems for the research laboratories. But the public should from the start be far better off than the students of the piano teacher who put in his window a sign reading: "Piano Lessons—Special Pains Given to Beginners."

GENERAL REFERENCES

(*1*) ROSENTHAL, A. H.: *Proc. I. R. E.*, **28** (1940), p. 203.

(*2*) ROBINSON, D. M.: *Proc. I. R. E.*, **27** (1939), p. 483, and following articles on Scophony developments.

(*3*) ROSENTHAL, A. H.: *Electronics & Television*, **13** (Feb.–Mar., 1940).

(*4*) ROSENTHAL, A. H.: *Electronic Eng.*, **14** (1942), p. 578.

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

26 (July, 1945), No. 7

The Museum of Modern Art Film Library (p. 226) — I. Browning

Rerecording 35-Mm Entertainment Films for 16-Mm Armed Forces Release (p. 232) — P. E. Brigandi

Electronic Industries

4 (Aug., 1945), No. 8

Television Optics (p. 80) — K. Pestrecov

Electronics

18 (July, 1945), No. 7

Supersonic Bias for Magnetic Recording (p. 126) — L. C. Holmes and D. L. Clark

International Photographer

17 (June, 1945), No. 5

The Adel Color Camera (p. 22) — W. J. Kenney

International Projectionist

20 (June, 1945), No. 6

Operation and Maintenance of the Filmosound V 16-Mm Projector (p. 7) — A. Nadell

Sound Reduction Amplifiers (p. 10) — R. H. Cricks

Motion Picture Projection in the Soviet Union (p. 13) — A. Nadell

Swiss Television System Combines Electron Beam and Arc Lamp (p. 14)

Projectionists' Course on Basic Radio and Television—Pt. 12 (p. 18) — M. Berinsky

New Continuous Projection System Invented by Canadian (p. 24)

20 (July, 1945), No. 7

A Step-by-Step Analysis of the Filmosound V 16-Mm Amplifier (p. 7) — A. Nadell

The Projection of Thomascolor Motion Pictures (p. 12) — L. R. Kistler

Sound Failure at Fine-Wire Contacts (p. 14)

Projectionists' Course on Basic Radio and Television—Pt. 13 (p. 18) — M. BERINSKY
DuMont's Projection Tele (p. 22)

Radio News

34 (July, 1945), No. 1
Color Television (p. 32) — R. W. EHRLICH

Television

2 (June, 1945), No. 5
Post-War DuMont Cameras (p. 11) — H. T. TAYLOR, JR.

SMPE

58th SEMI-ANNUAL TECHNICAL CONFERENCE

Hotel Pennsylvania, New York

October 15–17, 1945

« »

Directory of Committee Chairmen

Atlantic Coast Section and Local Arrangements	C. R. KEITH, *Chairman*
Papers Committee	BARTON KREUZER, *Chairman*
	C. R. DAILY, *Vice-Chairman*
Publicity Committee	HAROLD DESFOR, *Chairman*
Registration and Information	W. C. KUNZMANN
Membership and Subscription Committee	JAMES FRANK, JR., *Chairman, East Coast*
"Victory" Dinner-Dance	D. E. HYNDMAN
Hotel and Transportation	O. F. NEU
Projection Programs—35-mm	H. F. HEIDEGGER, *Chairman, assisted by* Members New York Projectionists Local 306
16-mm	M. W. PALMER

HOTEL RESERVATIONS AND RATES

No room reservation cards will be mailed to the membership either by the hotel or the Society and those who are contemplating attending this Conference should book their room accommodations *direct* with D. M. Mumford, Resident Manager, Hotel Pennsylvania, New York 1, New York, immediately. No rooms will be assured or available unless confirmed by the hotel management.

The following per diem room rates, European plan, are extended to SMPE members and guests when booking reservations direct with the hotel:

Room with bath, one person	$3.85–$7.70
Room with bath, two persons, double bed	5.50– 8.80
Room with bath, two persons, twin beds	6.60– 9.90
Parlor suites—living room, bedroom, and bath	$10.00, $11.00, $13.00 and $18.00

REGISTRATION

The Conference registration headquarters will be located on the 18th floor of the hotel adjacent to the *Salle Moderne*, where all technical and business sessions will be held during the 3-day Conference. Members and guests are expected to register. The fee is used to defray Conference expenses.

TECHNICAL PAPERS

Authors contemplating presentation of papers at this Technical Conference should submit *a complete manuscript* to the Papers Committee not later than October 1 for listing in the Final Program.

Only through your cooperation can the Papers Committee arrange a suitable program.

"VICTORY" DINNER-DANCE

An informal "Victory" Dinner-Dance, Journal Award presentation, distribution of Fellow Membership certificates to 1945 Fellows-elect, and a social get-together will be held in the *Georgian Room* of hotel, on Tuesday evening, October 16 (dress optional).

Tickets for this function should be procured at the registration desk not later than noon on October 16, so that hotel accommodations may be provided accordingly. Your cooperation is solicited.

LADIES' ENTERTAINMENT

There will be no official ladies' entertainment committee, or any prearranged program. However, the ladies will be welcome to attend any sessions of interest and the Dinner-Dance on October 16. Conference identification cards will be available to the ladies which will be honored at *deluxe* motion picture theaters in New York during the 3-day Conference. Application for these cards should be made at registration headquarters.

MOTION PICTURES

Conference identification cards issued to registered members and guests will be honored at *deluxe* motion picture theaters in New York, which will be listed on the back of these cards.

SESSIONS SCHEDULED

Monday, October 15, 1945

Open Morning.

10:00 a.m. *Hotel, 18th Floor:* **Registration.** Advance sale of "Victory" Dinner-Dance tickets.

2:00 p.m. *Salle Moderne:* **Opening session of Conference.**

8:00 p.m. *Salle Moderne:* **Evening Session.**

Tuesday, October 16, 1945

10:00 a.m. *Hotel, 18th Floor:* **Registration.** Advance sale of "Victory" Dinner-Dance tickets. Tickets must be obtained before noon to insure accommodations.

Salle Moderne: **Morning Session.**

2:00 p.m. *Salle Moderne:* **Afternoon Session.**

8:00 p.m. *Georgian Room:* **"Victory" Dinner-Dance.** Social get-together, dancing and entertainment.

Wednesday, October 17, 1945

Open Morning.

2:00 p.m. *Salle Moderne:* **Afternoon Session.**

8:00 p.m. *Salle Moderne:* **Evening Session.** Adjournment of the Fifty-Eighth Semi-Annual Technical Conference.

All technical sessions will open with an interesting 35-mm motion picture short.

IMPORTANT

Those desiring hotel rooms prior to and during the Conference should book their accommodations *direct* with the Hotel Pennsylvania management immediately. No rooms will be available at this hotel unless confirmed by them.

W. C. KUNZMANN
Convention Vice-President

SOCIETY ANNOUNCEMENTS

AMENDMENTS OF BY-LAWS

At a meeting of the Board of Governors held in New York on July 19, 1945, it was unanimously resolved to submit the following proposed amendments of the By-Laws to the membership of the Society for voting during the Fifty-Eighth Semi-Annual Technical Conference in New York, October 15–17, 1945, inclusive. Proposed changes are indicated in italics.

Proposed Amendment of By-Law I, Sec. 3 (b)

"Fellow membership may be granted upon recommendation of the Fellow Membership Award Committee, when confirmed by a three-fourths majority vote of the Board of Governors. *Nominations for Fellow shall be made from the Active membership.*"

Proposed Amendment of By-Law VII, Sec. 1 (5th paragraph)

"The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. *Voting shall close seven days before the opening session of the annual fall convention.*"

Proposed Amendment of By-Law XI, Sec. 6 (1st and 5th paragraphs)

"The officers and managers of a Section shall be Active, Fellow, or Honorary members of the General Society. *All officers and managers shall be elected to their respective offices by a majority of ballots cast by the Active, Fellow, and Honorary members residing in the geographical area covered by the Section.*"

"The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary-Treasurer, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. *Voting shall close seven days before the opening session of the annual fall convention.*"

EMPLOYMENT SERVICE

POSITIONS OPEN

Position open for man or woman with experience in optical instrument design. Position also open for man or woman with experience in lens design or computing. Write for interview. Binswanger and Company, Optics Division, 645 Union Ave., Memphis, Tenn.

Physicist with special training in optics for research on utilization of carbon arcs particularly in projection systems. Apply to Research Laboratory, National Carbon Co., Inc., P. O. Box 6087, Cleveland 1, Ohio.

Designer and engineer experienced in optics, lighting, and microphotography, capable of designing microfilm reading equipment and products related to microfilm industry. Reply to Microstat Corporation, 18 West 48th St., New York 19, N.Y.

Design engineer, experienced in mechanics and optics of motion picture cameras, projectors, and film scanning. Give details. Reply to Mr. John H. Martin, Columbia Broadcasting System, Inc., 485 Madison Ave., New York 22, N.Y.

POSITIONS WANTED

Sound recording engineer, 16- or 35-mm equipment, studio or location work, single or double system. Free to travel. For details write J. J. K., 354 Ninth Ave., New York 1, N.Y.

Honorably discharged veteran with 15 years' experience in all phases of motion picture production, including film editing, directing, producing. For details write F. A., 30-71 34th St., Long Island City 3, N.Y. Telephone AStoria 8-0714.

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

Director of visual training aids, now concluding government work, desires position with educational, industrial or commercial organization, supervising or assisting in the production or distribution of visual training or allied work. Write H. C. B., 348 Maryland Ave., Dayton 4, Ohio.

MEMBERS OF THE SOCIETY LOST IN THE SERVICE OF THEIR COUNTRY

FRANKLIN C. GILBERT

ISRAEL H. TILLES

MORGAN L. HOBART

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 OCTOBER, 1945 No. 4

CONTENTS

Indexes to the semi-annual volumes of the JOURNAL are published in the June and December issues. The contents are also indexed in the *Industrial Arts Index* available in public libraries.

JOURNAL

OF THE

SOCIETY of MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA • NEW YORK 1, N.Y. • TEL. PENN. 6 0620

Subscription to nonmembers, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscription or single copies of 15 per cent is allowed to accredited agencies. Order from the Society at address above.
Published monthly at Easton, Pa., by the Society of Motion Picture Engineers, Inc.
Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, Hotel Pennsylvania, New York 1, N. Y.
Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 OCTOBER, 1945 No. 4

REPORTS OF SMPE COMMITTEES

REPORT OF THE STUDIO LIGHTING COMMITTEE*

Summary.—*This report deals with operation and maintenance of studio lighting equipment. A previous paper*[1] *listed all of the various types of studio lighting equipment and gave data on the sizes and characteristics of carbon trims and incandescent bulbs.*

Illustrations and tables show the effects of proper and improper positioning of carbons in high-intensity arc units. Light output and color temperatures versus burning hours of incandescent bulbs are illustrated. The value of the use of tungsten powder as a cleaning agent in motion picture studio bulbs is shown. The effects of varying line voltages on studio light sources are described and illustrated.

CARBON ARC LIGHTING

The Rotating High-Intensity Arc.—In the high-intensity arc (Fig. 1) the positive carbon consists of a carbon shell or tube containing a core of a mixture of carbon and certain other substances which, under the action of the arc, volatilize and form a ball of extremely brilliant gases within a crater that is formed at the tip. The negative carbon also has a very small core which serves principally to keep the negative flame centered at the tip of the negative carbon.

Feed Control.—Studio-type high-intensity arc lamps are semiautomatic. When the lamps are in operation the feed motors are energized by current at the arc voltage. Therefore, if the line voltage drops, the current through the carbons will also drop reducing the carbon burning rate, and the carbons will tend to feed together. But as they approach each other the arc becomes shortened, the arc voltage drops and since the motor is energized at arc voltage, it will rotate slower on its reduced voltage and lower the carbon feed rate. In this manner a balance is automatically attained between carbon burning rate, arc voltage, feed motor speed, and carbon feed rate.

* Submitted June 7, 1945.

Once the arc control rheostat is set for proper feed rate and correct arc position is established very little manual adjustment is required.

Feed Control Motor Rheostat.—These high-intensity arcs are provided with a small control rheostat in the lamp mechanism motor circuit. By manipulation of the rheostat the positive and negative carbon feeds may be accelerated or retarded. For most operation the arrow on the rheostat knob should point up. Clockwise movement makes the feed faster, counterclockwise movement slows the feed.

In making the adjustment the rheostat should be set in closest conformity with the burning rate of the *positive* carbon and any necessary manual adjustment should be made with the negative feed control. After the feed motor is set to the burning rate of the positive carbon the automatic feature previously described, plus the negative-positive burning rates of the carbons, will tend to keep the arc in proper position.

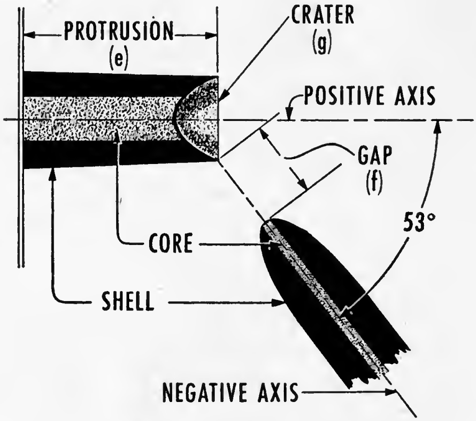


FIG. 1. Showing trade terms applying to the high-intensity arc.

The various tilt angles at which the lamps are placed affect the burning rates of the carbons, but once the lamp is adjusted for a given tilt angle the carbon feed control will require very little attention.

As a means of illustrating proper trimming of the studio types of high-intensity carbon arcs the carbon trim for the Type *170* unit is shown in Fig. 2. Table 1 shows comparable data for other types.

TABLE 1

Showing Data Regarding the Trimming of M-R Hi-Arcs

Lamp Type	Amp	Positive Carbon	Negative Carbon	Protrusion	Gap
170	150	16 mm × 20 in. M.P. Studio	$1/2$ in. or $15/32$ in. × $8^1/_2$ in. M. P. Studio	$1^5/_{16}$ in.	$1/2$ in.
90	120	13.6 mm × 22 in. M.P. Studio	$7/16$ in. × $8^1/_2$ in. M.P. Studio	$1^5/_8$ in.	$3/8$ in.
65	65	9 mm × 20 in. High Low Projector	7 mm × 9 in. Orotip C	$1^3/_{16}$ in.	$1/4$ in.

TABLE 2

Showing Effect of Varying the Protrusion

	Protrusion (In.)	Current	Arc Volts	Light
Protrusion Decreased	$1^1/_{16}$	115	76	46
	$1^1/_8$	130	72	58
	$1^3/_{16}$	138	69	76
	$1^1/_4$	143	68	83
Normal Operation	$1^5/_{16}$	148	67	100
Protrusion Increased	$1^3/_8$	152	64	110
	$1^7/_{16}$	165	62	105
	$1^1/_2$	167	59	97
	$1^5/_8$	168	58	76

Note.—An M-R Type *170* Hi-Arc was used on 115 line volts. The negative was kept in the normal position (*i. e.*, that which it assumed with a normal $1/2$-in. gap and $1^5/_{16}$-in. protrusion). The positive carbon was successively moved and allowed to burn 3 min in each position.

TABLE 3

Showing Effect of Varying the Gap

	Gap (In.)	Current	Arc Volts	Light
Gap Decreased	$1/4$	155*	61	77
	$3/8$	160	63	110
Normal Operation	$1/2$	148	67	100
Gap Increased	$5/8$	140	68	87
	$3/4$	135	69	74

* Arc unstable.

Note.—In this test a Type *170* Hi-Arc was operated on a line voltage of 115, in level position and the positive protrusion was kept to the normal $1^5/_{16}$ in. The gap was varied and the lamp permitted to burn for 3 min in each position. Readings were taken at the conclusion of each 3-min period.

The arc will operate satisfactorily if the protrusion is set so the lower lip of the positive carbon intersects the axis of the negative carbon (Fig. 2). When the lamp is in operation there should be a slight under flame lapping the outside of the lower crater wall as shown in Fig. 3.

Protrusion.—Table 2 shows what happens when the protrusion of the positive carbon in a Type *170* arc lamp is allowed to vary from the normal. Decreasing the protrusion lowers the current and decreases the light. Increasing the protrusion $^1/_{16}$ in. raises the light

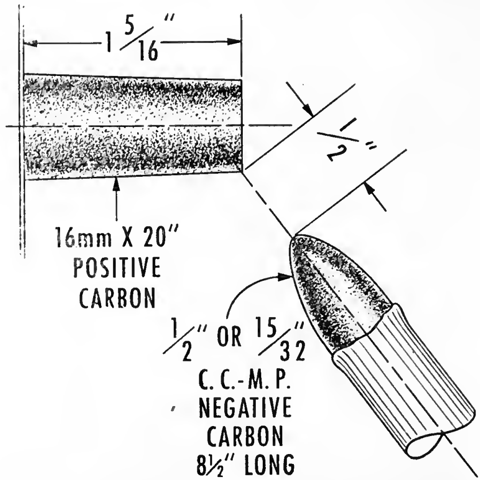


FIG. 2. Showing the "normal" trimming position of the carbons in an M-R Type *170* Hi-Arc.

level from a normal of 100 to 110 and raises the current from 148 to 152 amp. Each further increase of protrusion causes the light level to drop and the current to rise. These figures show the advantage of keeping the carbons in good trim position.

Fig. 3 illustrates the arc in proper burning position. Fig. 4 shows excessive protrusion and Fig. 5 too short a protrusion.

Varying Arc Gap.—Inasmuch as the arc stream is a path of electrical resistance the effect of shortening the arc gap is to decrease the arc voltage and increase the current and vice versa. Table 3 shows the effects of varying the arc gap.

Carbon Alignment.—To obtain maximum performance from a studio-type high-intensity lamp the axis of the negative carbon must center transversely (in a side-to-side manner) upon the axis of the positive carbon. Misalignment of the arc is indicated by a tendency of the tail flame to shoot out of the arc at an angle toward the right or left. The correction of faulty alignment is a simple maintenance problem.

Varying Line Voltage.—Variations of line voltage from stage to stage and from lamp to lamp are inevitable in the daily operations

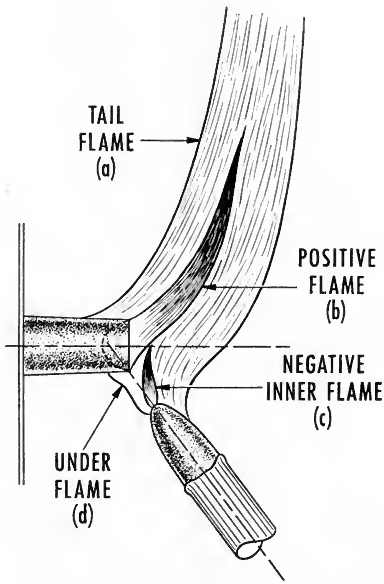


FIG. 3. Showing flame conditions of a high-intensity arc in an M-R Type *170* Hi-Arc.

of motion picture studios. The effects of line voltage variations are shown in Table 4.

High Line Voltage.—In the distribution of current on a motion picture set it is not unusual for lamps close to the main entrance switch to be operating at high voltage. This is possible particularly on large sets where stage voltage may be boosted to overcome the voltage drops in long distribution lines. High voltage evidences itself in the negative carbon by a tendency to spindle, that is, to burn to a long slender tip. Also under high voltage conditions arc action may become erratic and lamp grids tend to heat abnormally. The correction within the control of the operator is to lengthen the arc by maintaining normal protrusion and increasing the arc gap. Lengthening the gap increases the arc resistance and reduces the current.

Low Line Voltage.—In the rigging of sets and in changes of lamp position on a set certain circuits may be overloaded with a result that lamps in such circuits will be operating at considerably less than rated voltage. When high-intensity arcs are operated at lower

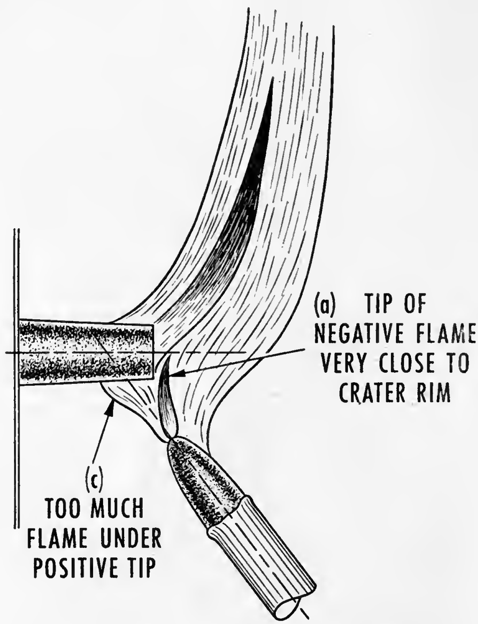


FIG. 4. Showing the effect of excessive protrusion.

than normal voltage the current is reduced, the negative carbon burns with a very blunt tip, the arc stream tends to wander around the negative carbon tip, and the arc becomes unsteady. A wandering arc, a blunt negative carbon tip, and low light output are visible evidences of low line voltage.

The remedy within the control of the lamp operator is to shorten the gap and keep the arc protrusion close to normal. This will reduce the resistance of the arc, bring the current more closely to operating standard, and will raise the light level to a marked degree.

Reverse Polarity.—In operation it is essential that the positive carbon be connected to the positive side of the line and the negative carbon to the negative side. When they are connected in the opposite way they are said to be in reverse polarity.

When a lamp connected in reverse polarity is switched on and struck, the arc immediately starts to act erratically. If allowed to

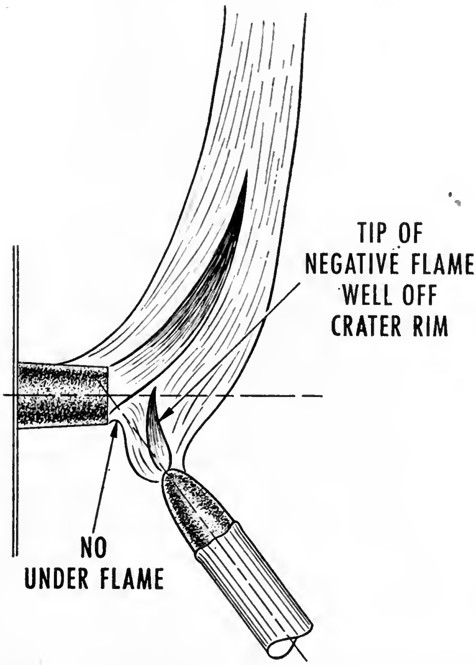


FIG. 5.—Showing the effect of too short a protrusion.

burn in this condition for more than a few seconds, the core will be burned out of the negative carbon to a considerable depth and frequently the tip of the positive carbon will be split or shattered.

When operating a lamp for the first time after it has been connected to the line the polarity should be checked by starting the unit. If the arc action indicates an error in connection, it should be shut off immediately and the pin connectors at the lamp should be reversed. Polarity should be checked on all lamps as soon as possible after they are connected to avoid possible delays when photographic operations begin.

TABLE 4

Showing Effect of Varying the Line Voltage

	Line Volts	Current	Arc Volts	Light
Line Volts Decreased	100	128	58	55
	105	133	61	61
	110	138	63	86
Normal Operation	115	148	67	100
Line Volts Increased	120	159	69	118
	125	167*	72	130

* Arc overloaded.

Note.—In this test a Type *170* Hi-Arc was operated with its trim at all times in normal relation (*i. e.*, with $1^5/_{16}$-in. protrusion and $^1/_2$-in. gap). The voltage was varied and readings were taken at the conclusion of a 3-min burning period at each successive voltage.

INCANDESCENT BULB LIGHTING

Filament lamp sources require a minimum of attention on the part of studio lighting technicians. Because of this characteristic, filament lamp equipments may not get the little attention they should have to insure that they give maximum performance and operate at proper color temperature. The latter is of particular importance in color photography as the spectral quality of the illumination provided must be closely controlled. The illustrations and discussions which follow are devoted to the larger sizes of filament lamps, *i. e.*, the 1-, 2-, and 5-kw bulbs most commonly employed on studio sets. Many of the points apply equally to the smaller sizes of lamps.

Effect of Line Voltage Variations.—All incandescent lamp bulbs designed for operation in multiple on either d-c or a-c circuits are marked as to wattage and voltage. In the case of the 1- and 2-kw lamps, the additional marking *MP* is used to identify the lamps for use in black-and-white photography and *CP* for color photography. The 5-kw and 10-kw lamps are suitable for *either* black-and-white or color photography and are marked *MP-CP* which indicates that they are interchangeable. In the future, the *MP-CP* marking may be deleted as their application in airport floodlighting is increasing.

Fig. 6 shows the effect of varying line voltage on the light output, watts consumed, and color temperature of the *CP* line of studio lamps. The curves apply to lamps marked 120 v and the 3 curves cross at the 120-v point on the chart. The curves would be identical in shape and slope if drawn for lamps marked 115 v; however, the curves would then cross the 115-v point on the chart at a value of 3350 K and 100 per cent initial light output and watts. This simply means that lamps *labeled* 120 v must have 120 v at the lamp terminals (not at the panel board) if rated light output is to be obtained, normal wattage consumed, and proper color temperature realized. Similarly, lamps *labeled* 115 v must be *operated* at 115 v to attain designed performance. If the lamp socket voltage is 5 v below rated lamp voltage, the watts

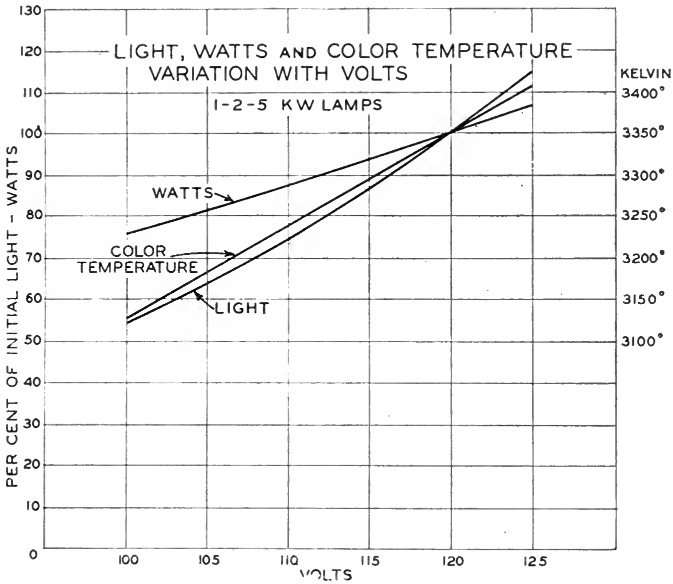


FIG. 6. Some characteristics of gas-filled tungsten lamps when operated at voltages other than at their rated design values. Accurate voltage control is of particular importance in color photography.

will be reduced approximately 6 per cent, color temperature about 55 K, and light output 14 per cent.

Unfortunately, the human eye cannot readily detect light output and color temperature variations caused by a 5- or 10-v drop in feeder voltage. A voltmeter, connected across the bulb terminals in the lamp house, is the most positive check and one that can be made simply.

Low socket voltage is most often attributed to overloaded feeder cable. However, other factors, such as burned switch points and poor connections—at plugging boxes and at the lamp socket itself—

can be contributing factors. A 5-kw incandescent bulb operates at approximately 45 amp. Poor connections at the bipost lamp terminals at this current value will cause rapid oxidation and pitting of the lamp posts and socket sleeves. These connectors require frequent inspection to insure clean and tight contacts. Bipost sockets designed to grip firmly the entire lamp post rather than to cut into the copper shell at one point with a set screw, are preferred types. A poor lamp connection can be quickly checked by removing the bulb from the holder and inspecting the lamp posts for oxidation pits.

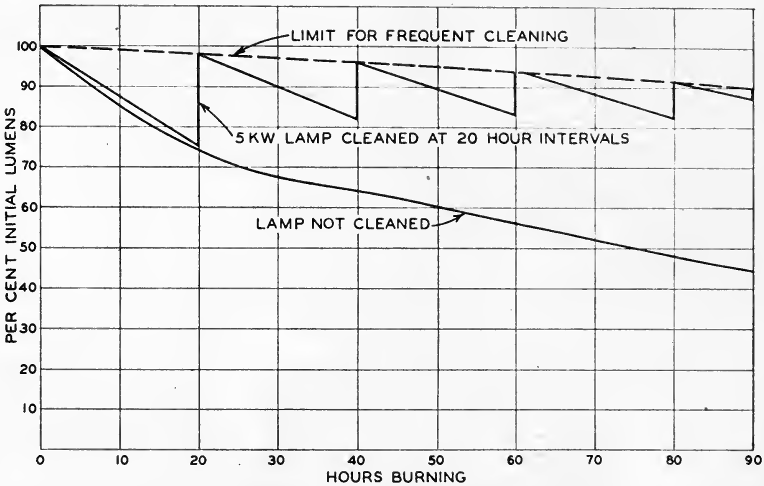


FIG. 7. Total light output of high-wattage lamps can be restored to approximately their initial value by swirling the tungsten powder in the bulb. Although the total light output in lamp bulbs not cleaned falls off as shown above, most of the blackening occurs on the glass bulb directly above the filament and the useful light passed through lens-type spotlamps is not reduced in these amounts.

Importance of Tungsten Cleaning Powder.—High-wattage lamp bulbs in the 2-, 5-, and 10-kw sizes are available with or without tungsten cleaning powder. Proper use of this cleaning agent, Fig. 7, results in lamp performance at close to initial light output throughout the lamp's useful life. Good maintenance practice indicates that the bulb should be removed from the lamp house after every 20 hr, and preferably every 10 hr, of burning and the tungsten powder swirled about in the bulb. It is appreciated that accurate records of burning hours cannot be kept on studio lamps. However, whenever lamp bulbs are removed from the units for any reason or when an inspection reveals that considerable blackening has accumulated, it is worth the effort to shake the powder about the bulb for a few seconds. Although some technicians prefer not to remove bulbs until they have burned out, because of the hazard of dropping or breaking the bulb, Fig. 7 indicates that worth-while gains in total light output are possible if a reasonable amount of care is exercised when cleaning lamps.

In addition to the gain in over-all light output throughout life when lamps are cleaned, longer useful life results as the lamp bulb operates cooler and has less tendency to blister when the blackening is periodically removed. This is particularly true in the case of the

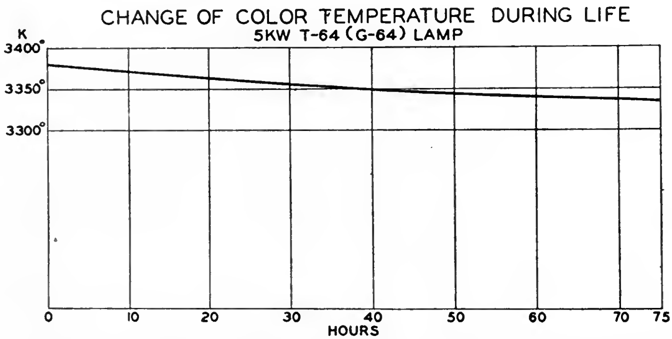


FIG. 8. Color temperature characteristic of 5-kw studio lamps during life applicable to lamps that are cleaned at least every 20 hr of burning by swirling the tungsten cleaning powder about in the bulb.

spherical or *G64* bulb lamps as their bulb volume is approximately 25 per cent less, and the heat correspondingly greater than in the improved tubular *T48* bulb lamps.

Color Temperature during Lamp Life.—In the past, color temperature of incandescent lamp bulbs was rated in terms of initial performance. The *CP* line of lamps had an initial rating of 3380 K. A more useful rating is the mean color temperature value, and all lamps used for photographic purposes are so rated today. This change is in rating only as no changes in physical or electrical characteristics have been made. Fig. 8 shows the color temperature performance throughout life of 5-kw lamps which have an average rated life of approximately 75 hr. Midway in life, the color temperature of the average lamp is approximately 3350 K, which is approximately 30 degrees lower than it was initially and will drop approximately 20 degrees more when the lamp reaches rated life. If the color requirements on a particular set are such that use of the lamp should not be continued, even though it is still operative after some 75 hr of use, it can be used on black-and-white sets in either lens spotlamps, sun-spots, or skypans. The color temperature at this point in life is still appreciably above that in the lower wattage line of *MP* lamps, which are designed for certain life values rather than for a mean color temperature value.

General Maintenance Hints.—All of the above discussion has been directed to the operation and maintenance of the lamp bulb itself. Other parts of the lighting equipments require periodic maintenance if maximum over-all efficiency of the generated light is to be utilized. Dirt and film on glass and metal reflectors absorb considerable light if allowed to go any appreciable time without cleaning. It should be remembered that light from the lamp bulb must go through any layer of dirt on the mirror twice—once, in getting to the specular surface, and again when leaving it. Special compounds are available for quickly cleaning without injury to the specular surfaces. Similarly, condenser lenses, such as the Fresnel type, must be kept clean for maximum efficiency.

Studio Lighting Committee

C. W. Handley, *Chairman*

J. W. Boyle R. E. Farnham Karl Fruend
J. J. Chanon W. W. Lozier

REFERENCE

[1] Linderman, R. G., Handley, C. W., and Rodgers, A.: "Illumination in Motion Picture Production," *J. Soc. Mot. Pict. Eng.*, **XL** (June, 1943), p. 333.

REPORT OF THE COMMITTEE ON STANDARDS*

The Committee on Standards of the Society of Motion Picture Engineers has been active in recent months primarily through individual memberships in the various subcommittees of War Standards Committee on Photography and Cinematography, Z52, of the American Standards Association, where the urgent needs of the Armed Services have resulted in an unprecedented rate of motion picture standardization, particularly in the 16-mm field. These War Standards are now under consideration from a peacetime point of view, with the early objective of establishing those suited to the peacetime economy on a more permanent basis.

The Committee has under consideration a total of 8 other projects, of which only 2 have been receiving attention during wartime. The first of these has to do with the dimensional characteristics of 35-mm projector sprockets where a slight increase in diameter gives promise of providing a substantial increase in film life. Dr. Carver expects to have a report[1] of his subcommittee's activities in this connection ready for presentation at the Fifty-Seventh Semi-Annual Technical Conference. A second project is the development of a glossary of terms used in the motion picture industry, which has not been pushed very hard because of more important wartime demands. Nevertheless, a considerable amount of progress has been made and a more active prosecution of this project is being planned for the early future.

In anticipation of a more aggressive post-war program, the membership of the Committee on Standards has recently been enlarged to 47 individuals, thus providing a more representative group including all fields of the motion picture industry. Many of the new members were chosen because, along with older members, their excellent contributions to the activities of the ASA War Committee have indicated unusual ability in their particular field. Thus, although the Committee on Standards as an organization has been in comparative hibernation during the war years, the membership is being maintained in a state of active training for the peacetime work to come.

F. T. BOWDITCH, *Chairman*

REFERENCE

* Presented May 14, 1945, at the Technical Conference in Hollywood.

[1] "Report of the Subcommittee on Projector Sprocket Design," *J. Soc. Mot. Pict. Eng.*, **45**, 2 (Aug., 1945), p. 73.

REPORT OF THE SUBCOMMITTEE ON SCREEN BRIGHTNESS*

The basic assignment of this Subcommittee of the Theater Engineering Committee of the Society has been, and still is, to find, or cause to be developed, instruments for measuring the uniformity and level of screen brightness and screen illumination. Since no instrument has been available having properties desired by the Subcommittee as outlined in a previous report,[1] development work on the part of instrument manufacturers is needed. Such development work has been out of the question during the war and the Subcommittee has therefore been unable to proceed.

In anticipation of relaxed pressure on development engineers in connection with war projects, the Subcommittee is now again active. The original specifications have been reviewed and approved, and letters have been sent to instrument manufacturers inviting their consideration of this problem. It is still too soon to know which ones may be willing to docket this project as very few replies have been received so far.

F. E. CARLSON, *Chairman*

REFERENCE

[1] "Report of Subcommittee on Screen Brightness," *J. Soc. Mot. Pict. Eng.*, **XXXVIII**, 1 (Jan., 1942), p. 81.

REPORT OF THE SUBCOMMITTEE ON THEATER ENGINEERING, CONSTRUCTION, AND OPERATION*

There has recently been formed a new committee of the Society, the Subcommittee on Theater Engineering, Construction, and Operation. This is a subcommittee of the Theater Engineering Committee which is under the chairmanship of Dr. Alfred N. Goldsmith. The membership is as follows:

HENRY ANDERSON, *Chairman*

H. BARNETT	T. T. GOLDSMITH
H. J. BENHAM	A. GOODMAN
F. E. CARLSON	J. J. HOPKINS
W. B. CUTTER	C. F. HORSTMAN
W. L. FLEISHER	E. R. MORIN
J. FRANK, JR.	BEN SCHLANGER

J. J. SEFING

* Presented May 14, 1945 at the Technical Conference in Hollywood.

We believe that this Subcommittee will be most effective in extending the activities of the Society by offering needed technical assistance to the motion picture theater industry. The Subcommittee intends to function in 2 principal ways:

First, it plans to investigate a number of special subjects relating to theaters, and to develop information valuable to the theater operator on such subjects as Theater Illumination, Ventilation, Cooling, and Air Conditioning, Acoustics, Seating, Theater Carpets, *etc.*

The Subcommittee will make a special effort to discover new applications to theater construction and operation of materials, processes, and inventions which have arisen out of the war effort.

The Subcommittee has already instituted a study of the subject of Theater Carpets. The whole group of subjects is highly technical and worthy of study by the Society's best engineering talent. It has been learned that while carpets have been developed to a high degree of perfection over a period of several thousand years by trial and error methods, there is nevertheless much research work being carried on by the larger manufacturers, and the Association of Carpet Manufacturers has an active Research Committee.

The manufacturers have been discouraged to find that, in spite of the efforts devoted to improve their product, a great deal of the effort is nullified by the consumer, of which the theater is one, who may in general be said to install and maintain his carpets in an unscientific, even unintelligent, manner. The Subcommittee is convinced, as are also the manufacturers, that in view of the huge sums spent by the theater industry for carpets, it may be instrumental in saving the motion picture industry very substantial sums of money now wasted because of improper carpet specification, installation, and maintenance.

Secondly, the Subcommittee will establish a suggested set of standards for theater construction and operation. At the present time numerous cities and states are extensively revising their building codes, and such codes in all instances contain special sections relating to theaters. Most of these codes have been developed by carrying along old untried specifications plus the introduction of new equally untried specifications. The industry has been at a disadvantage in meeting with code makers, for the industry has been poorly equipped with technical information necessary for dependable and useful standardization.

It is the intent of this Subcommittee to assist the industry in the development of reasonable codes, by endeavoring to develop reasonable standards for such things as theater seating, theater illumination, stage curtains, stage skylights, exit facilities, and many other factors, that go into the development of a code.

The Chairman of the Subcommittee is a member of a committee appointed by the State of New York Labor Department which is now formulating a code covering all places of public assembly in the State. He is, therefore, informed upon the needs of a code-making authority. He has reported that the Recommended Standards of the Society of Motion Picture Engineers for Motion Picture Projection Rooms have been of great assistance to the New York State Committee and that the Society's standards will to a large degree be included in the new State code.

The Subcommittee will coordinate its efforts with the other committees of the Society. It will value comments and suggestions from the membership.

HENRY ANDERSON, *Chairman*

TWO NEW EASTMAN FINE-GRAIN SOUND RECORDING FILMS*

R. M. CORBIN,** N. L. SIMMONS,† AND D. E. HYNDMAN††

Summary.—*Eastman Fine-Grain Sound Recording Film Types 1372 and 1373 have been introduced recently to the motion picture trade. Type 1372 is a film having high contrast and with capabilities of producing a high degree of image sharpness for variable-area recording. This emulsion may be used for recording with ultraviolet or white light with very little difference in sound quality. High energy developers are not necessary for the development of this film owing to the inherent lack of image spread. Type 1373 is a film designed for development in a normal picture developer for variable-density recording. The use of special low energy developers is therefore avoided. Test data are presented for these 2 films.*

The development of suitable sound films has entailed the meeting of a great number of requirements and there have always been some that were in direct conflict. There have been many cases where a film that was capable of giving very good results did not fit into the methods of operation and was therefore judged unsatisfactory. It is required that a sound negative material be capable of being exposed on the type of recorder in use and so developed that when printed upon the release print and developed with it under conditions that give the best in picture quality, the sound will also be the best obtainable. Changes in recording technique and in materials used in making prints may call for a new sound film. In developing these 2 new Eastman Sound Films, Type *1372* for variable-area recording and Type *1373* for variable-density recording, all latest developments have been taken into account. Where conflicting requirements have been encountered, the requirement of sound quality has been favored.

HISTORICAL RÉSUMÉ

Prior to 1932, the Eastman film which was used for sound recording purposes was Eastman Release Positive, Type *1301*. This film was,

* Presented October 17, 1944, at the Technical Conference in New York.

** Motion Picture Film Dept., Eastman Kodak Co., Rochester, N. Y.

† Motion Picture Film Dept., Eastman Kodak Co., Hollywood.

†† Motion Picture Film Dept., Eastman Kodak Co., New York.

of course, designed for use as a print stock but was found to give reasonably satisfactory results when used for either variable-density or variable-area sound records. At that time, however, the emulsion speed was slightly low for variable-density recording. Also, it was a high-gamma material and development to the low gamma required made control of development rather difficult.

In 1932, Eastman Sound Recording Film, Type *1359*, was made available for variable-density recording. This film had considerably more emulsion speed than *1301*. It was, like *1301*, however, a high contrast film. In 1936, for variable-area recording with ultraviolet light, Eastman Sound Recording Film, Type *1357*, was submitted to the trade. Gradually Type *1357* supplanted Type *1359* for use as a variable-density recording medium.

In 1937, the first Eastman Fine-Grain Sound Recording Film was received in Hollywood. This film, Type *1360*, was orthochromatic and was designed for use in variable-area recording. It was found to be superior to Type *1357* because of improved high-frequency response and reduced background noise. Type *1360* was also found to give improved sound quality over the older materials when used as a rerecording print stock for rerecording purposes. It had the disadvantage of being finer grain and having much less image spread than the print stock then in use, and a very high density was required to produce satisfactory cross-modulation. This made the effective speed too low for many users.

About 1937 there was generated a great amount of interest in the use of fine-grain films for sound, and experiments were run using all the available fine-grain films for recording and rerecording. In 1939, Type *1361* was introduced as a fine-grain rerecording print stock with the idea that a fine-grain material at this point would serve as much purpose as a fine-grain negative. Later in 1939, however, Type *1302*, Eastman Fine-Grain Release Positive, was introduced and there was no further need for a film like Type *1361*.

Up to that time there was no fine-grain sound recording film available with a satisfactorily slow developing rate for variable-density negatives. In fact, all the films used for variable-density sound recording up to that time, whether fine grain or non-fine grain, had been of the inherently high-gamma infinity type.

In November, 1939, Eastman Fine-Grain Sound Recording Film, Type *1366*, which possessed a slow development rate, was made available. This film was used successfully at low gamma values for variable-density sound recording. A very low control gamma was required for this film and under that condition the speed was not quite great enough for most users.

Since all fine-grain films which had been manufactured up to 1939 had given brown-toned screen images, because of the inherent light-scattering properties of very fine silver bromide grains, no great interest had been shown in using these films for release print stock. A method was found for producing a black-toned image on Eastman Fine-Grain Release Positive, Type *1302*, late in 1939, and this film has found widespread use as a release print material since that time. It is used to a limited extent for variable-area recording with white light and serves very well for this purpose. It is not deemed satisfactory as a variable-density sound recording stock because of its inherent high gamma and rapid development rate.

Fine-Grain Sound Recording Film, Code *1370*, which was first sold in 1940, was a low gamma infinity emulsion capable of high resolving power. However, it still required the use of the so-called variable-density sound type of developer, which produces a slower developing rate than normal picture negative developer. This type of developer has always been necessary for development of variable-density sound track, because of the necessity for obtaining extremely low gamma values on films which have generally been of the high gamma infinity, or positive-film type.

The need was apparent for a variable-density sound recording film, having low gamma infinity, which could be handled at normal times of development in a regular picture negative developer. Experiments were started toward that end, and early in 1944 Eastman Fine-Grain Sound Recording Film, Type *1373*, was produced.

The rapid growth of 16-mm production during the past few years had emphasized the need for a variable-area sound recording film capable of extremely high resolution. To satisfy this demand, Eastman Fine-Grain Sound Recording Film, Type *5372*, in 16-mm width, was produced in 1942. This film has received wide acceptance by the 16-mm professional trade and has proved to be a superior product in all ways. Extensive tests were begun, with the cooperation of RCA on the same emulsion in 35-mm width, which have shown that this film is superior for 35-mm variable-area sound recording.

At the present time, the Eastman films which are being used by the motion picture industry for variable-area sound recording are

Types *1357*, *1302*, and *1372*. Those being used for variable-density sound recording are Types *1357*, *1301*, and *1373*. In the consideration of the emulsion characteristics, the physical characteristics, and the results of sound quality tests on *1372* and *1373*, comparisons will be made with other Eastman films now being used for sound recording purposes.

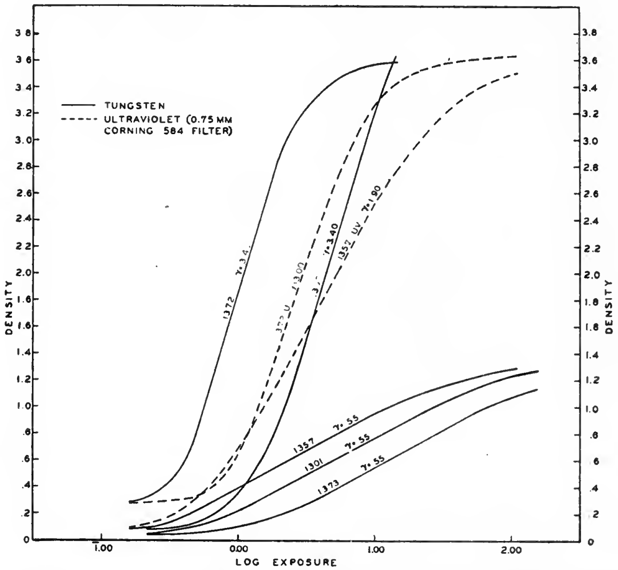


FIG. 1. Eastman Sound Recording films, exposed to tungsten and to ultraviolet radiation, IIb sensitometer. Average Hollywood conditions of use.

TYPE 1372—FOR VARIABLE-AREA SOUND RECORDING

Advantages.—Type *1372* emulsion possesses several outstanding emulsion characteristics when compared with older well-known variable-area sound recording films, such as Types *1302* and *1357*. These are enumerated as follows:

(*1*) Emulsion speed comparable to *1357* when both are exposed with ultraviolet light; higher speed if *1372* is exposed with white light; and *1357* to ultraviolet light.

(*2*) Higher resolving power and less image spread.

(*3*) Emulsion sensitivity confined largely to that region of wavelengths to which the emulsion shows strong absorption, *i. e.*, the ultraviolet and violet region. Thus there is little need for ultraviolet filters in exposing this film.

(4) Sufficient image sharpness for use as a sound negative when developed in ordinary positive developers of the *D-16* type; does not necessitate the use of special high-energy developers now used for all 35-mm variable-area sound recording films.

Emulsion Characteristics.—In Fig. 1 are given typical H and D curves for the Eastman sound recording films as they are used at the present time. The ultraviolet exposure curves for both *1357* and *1372* were made by replacing the standard positive conversion filter

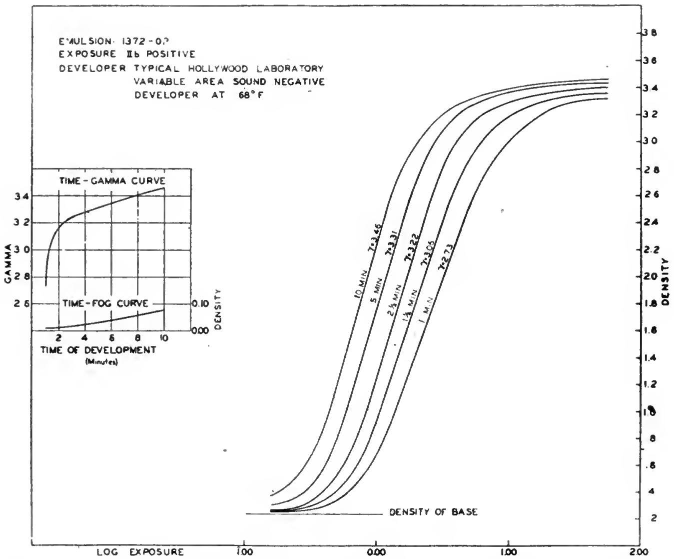


FIG. 2. Sensitometric curves of Eastman Fine-Grain Sound Recording Film, Type *1372*. Typical Hollywood processing conditions.

(No. *78B*) in the IIb sensitometer with a Corning *584* filter, 0.75 mm thick. The log E scale given in Fig. 1 is, therefore, not a true scale for the ultraviolet exposures.

All ultraviolet recorder exposures mentioned in this paper were also made with the 0.75-mm Corning *584* filter.[1] The Corning *597* filter, 3 mm thick, which is also used for ultraviolet recording, has considerably wider transmission limits, and thus produces more exposure on either *1357* or *1372* emulsions.

The high-contrast curves on *1372*, *1357*, and *1302* in Fig. 1 are the result of 7 min development in the variable-area sound negative developer in a representative laboratory. This constant time of development for all films is fairly typical of trade practice. At such development conditions, the films used for variable-area sound recording have reached, or at any rate closely approached, gamma infinity for the type of developer used. In comparing *1372* with *1357*, the considerably higher contrast of *1372* is noteworthy; in comparing *1372* with *1302* the large advantage in emulsion speed of *1372* when both films are exposed with white light is evident. The large differences in the "toe shapes" of these 3 emulsions are quite apparent from the typical curves given in Fig. 1.

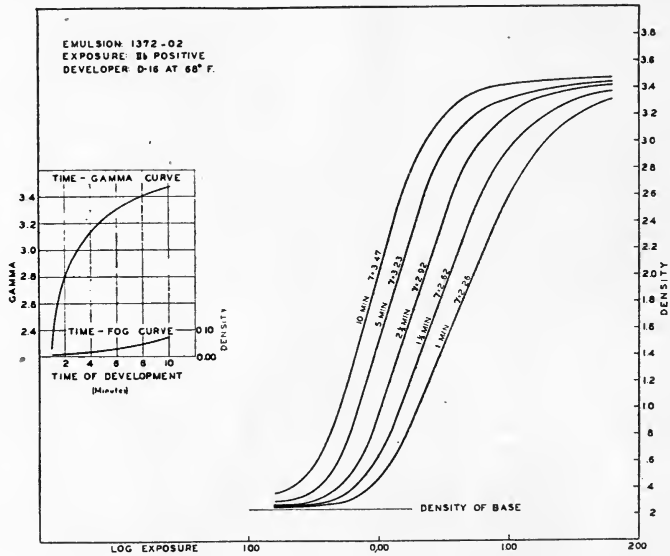


FIG. 3. Sensitometric curves of Eastman Fine-Grain Sound Recording Film, Type *1372*. Developed in *D-16* under same conditions of agitation used for curves obtained in Fig. 2.

For variable-area recording a high contrast is desirable so that the exposed areas will develop to a high density while the unexposed areas remain clear; the boundary between the two must be as sharp as possible. Thus, the ability of the *1372* emulsion to reproduce geometrically sharp edges, which is known as sharpness, is a factor of prime importance in the choice of an emulsion for variable-area sound recording. Since the density gradient at the edge of the image of a geometrically sharp-edged object in general follows the same curve as does the H and D characteristic of the emulsion, it is apparent that not only gamma but also toe shape is of importance in the selection of an emulsion to give maximum resolution of high frequencies in a variable-area sound record.[2] The resolving power of *1372* is 150 lines per mm, *1302* resolves 90 lines per mm, and *1357* resolves 50 lines per mm. The manner of arriving at such test values of resolving power has been discussed by Mees.[3]

Figs. 2 and 3 give families of sensitometric curves obtained with *1372,* when this film is developed in a typical Hollywood variable-area sound negative developer and in *D-16.* Both developments were carried out in the same developing machine, and the rates of development are believed to be fairly representative of laboratory practice.

There are 3 developer formulas which should be considered in a study of development conditions for *1372.* These are given in Table 1.

TABLE 1

Developers Used for Variable-Area Sound Recording Films

Chemical	*D-16*	Release Positive Developer	V.-A. Sound Negative Developer
Elon	0.3	1.5	2.0
Hydroquinone	6.0	3.0	11.0
Sodium sulfite, des.	38.0	40.0	40.0
Potassium bromide	0.9	2.0	2.0
Sodium carbonate, des.	19.0	?	?
Citric acid	0.7	..	..
Potassium metabisulfite	1.4	..	..
*p*H	10.0	10.0	10.4

All quantities expressed as grams per liter of solution.

The formula entitled "Variable-Area Sound Negative Developer" is representative of developers of that type used by motion picture laboratories, but is not to be regarded as the best recommended formula for use under all sets of operating conditions. This formula was used to obtain the curves shown in Fig. 2. The formula entitled "Release Positive Developer" is believed to be representative of positive developers now in use for developing motion picture film. It should be noted, however, that there is wide variation in the chemical composition of positive developers used by motion picture laboratories, so that statements made with reference to the formula given in Table 1 should not be construed as applying to all positive developers.

It has been found that development of *1372* in the "Release Positive Developer" of Table 1 does not give as satisfactory results as does development in *D-16* or the "Variable-Area Sound Negative Developer." Gamma values are much lower, toe break density values are higher, and cancellation tests show the tolerance of operating limits to be narrower than those obtained in either of the other 2 formulas. It will be noted that the hydroquinone content of the "Release Positive Developer" is low in comparison with that of the other developers. It is believed that tests should be made in the regular positive developer at any laboratory at which emulsion *1372* is to be developed before the decision is made as to whether a satisfactory variable-area sound negative can be obtained in this manner. Formulas of the *D-16* type have been used quite successfully in some commercial laboratories for the development of 16-mm *5372* as well as either regular or fine-grain 16-mm release print stocks.

At the present time 4 Hollywood laboratories maintain special high-energy developers for the development of variable-area sound negative and rerecording prints. One Hollywood laboratory has used for this purpose the regular positive developer at prolonged times of development. The other Hollywood laboratories do not handle any variable-area sound track. To date all production work on 35-mm *1372* done in Hollywood has been developed in the high-energy type of developer, but from a study of the results in *D-16* one is led to the conclusion that where it is possible to use a positive developer with a higher developing agent concentration and a higher hydroquinone-elon ratio, Type *1372* can be handled in the same developer and thus eliminate the necessity of a special sound developer.

From a study of the families of curves in Figs. 2 and 3, it may be seen that there are a multiplicity of combinations of exposure and development conditions which lead to equivalent densities at very nearly equivalent gamma values. While, on the other hand, this fact allows considerable leeway in the exposure and development conditions, yet, on the other hand, it behooves the sound and laboratory technicians to determine, by a series of controlled tests, which combination of these conditions results in the best quality.

As stated earlier in the paper, it is not necessary to use an ultraviolet filter with Type *1372* since the image spread is very low. Since a filter is not needed the effective speed is high, being about $2^1/_2$ times that of Type *1357* with the commonly used ultraviolet filters. If, however, it is thought desirable to use a filter, the spectral sensitivity of Type *1372* is such that there is a minimum speed loss with the introduction of a violet filter. With the commonly used filters, Type *1372* is approximately as fast as Type *1357* with the same filter.

Fig. 4, the wedge spectrogram of *1372* emulsion, shows that the sensitivity of this film extends to about 460 mμ at the long wavelength end. This value is somewhat lower than the corresponding long wavelength limit of sensitivity of other sound recording emulsions. This fact, coupled with the relatively high emulsion speed, evident in Fig. 1, is proof that *1372* possesses a much higher ultraviolet to white light sensitivity ratio than do other sound recording films. The measured ratios of IIb ultraviolet to white light sensitivities are: *1357*—1 to 10; *1302*—1 to 8; *1372*—1 to 3. These values represent the ratio of exposure necessary to produce densities of 2.0 for equal development times.

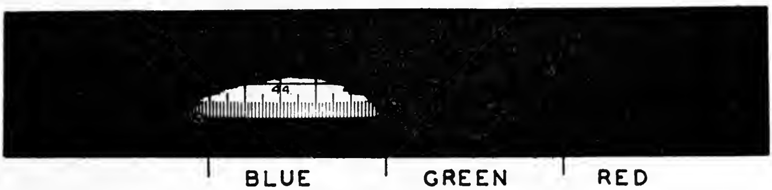


FIG. 4. Spectrogram of *1372* to tungsten light.

Under the conditions of forced development used for variable-area sound records, safelight fogging becomes a matter of real concern. Too frequently, it is believed, fog which is attributed to the chemical action of the high-potential developer, is actually the result of too long exposure to light of very low intensity level. Results of an exaggerated safelight fogging test on *1372* and other films used for sound recording are given in Table 2. Test conditions were arbitrarily chosen. An *OA* safelight, 8 × 10 in. in size, containing a 15-w lamp, was placed at a distance of 3 ft from the film emulsion surface, and the direct radiation from the safelight allowed to fall on the film. Development was for normal time in a variable-area sound negative developer.

TABLE 2

Safelight Fog Densities

	Exposure Time to *OA* Safelight, in Min			
Emulsion	0	2	5	10
1372	0.02	0.02	0.02	0.02
1302	0.02	0.02	0.04	0.06
1357	0.04	0.06	0.08	0.16

The support upon which *1372* emulsion is coated carries a gray anti-halation backing which serves to reduce still further the many possible causes of an unsharp image.

Type *1372* has a thinner emulsion than either *1357* or *1302* and recorders should undoubtedly be refocused for optimum results on this film. Those made with and without focusing, however, have not shown too great a difference.

Sound Quality Test Results.—Examination of high-intensity H and D curves obtained on *1372*, using both ultraviolet and white light, shows the curve shapes to be identical with IIb curves which have been given the same development. The high-intensity exposures were made on an improvised sound recorder. The light intensity was modulated with a series of neutral density filters, and the exposure time approximated the mean value used in an actual sound recording.

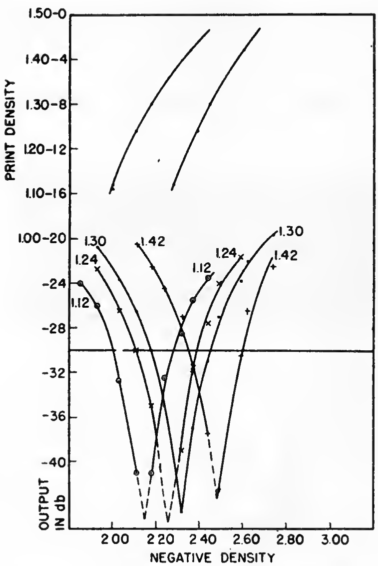


Fig. 5. Cross-modulation tests, negative developed in *D-16*.

Results of recorder exposure tests, high-frequency attenuation measurements, and cross-modulation tests made by RCA on Type *1372* have been reported in another paper presented before this Society.[4] Consequently, only a brief summation of the advantages of this film from the standpoint of sound quality will be presented here.

Listening tests give emulsion *1372* a positive advantage in quality over the older types of film, particularly because of the absence of background noise of the type which is usually considered to be inherent in the film, *i. e.*, caused by graininess, fog, and film surface characteristics.

Cross-modulation tests, developed in either *D-16* (Fig. 5) or the special variable-area sound negative developers now used in Hollywood, show *1372* to have wider print density tolerance limits for −30 db cancellation than any of the older types of film. When used in place of *1302* for a rerecording print stock, the tolerance limits are still broader. The optimum negative density is in the range 2.6 to 2.8 for best cancellation at a normal print density of about 1.2 to 1.4, when the negative is developed to the IIb gamma control value of approximately 3.0 to 3.5. These limits apply to either ultraviolet or white light exposure of the *1372* negative. For these negative conditions, an optimum rerecording print density of 1.8 to 2.0 is found for *1302* and 2.5 to 2.7 for *1372*.

The high-frequency response is improved to the extent of about 2 db at 9000 cycles when *1372* is compared with *1357* as a recording stock and both are printed on *1302*. This gain is noted with *1372* for either a rerecording print or release print development conditions. The use of *1372* as a print stock adds a further improvement in high-frequency response.

The comparatively small amount of image spread in *1372* emulsion makes it possible to use it as a direct positive at densities of from 1.2 to 1.3, whereas most films require a density of about 0.6 to 0.8 for minimum distortion. At this low density level, the volume output is too low and the noise level too high for satisfactory use of these films as direct positives.

When *1372* is used for rerecording prints or for daily prints, a loss in volume, attributable to the gray base density, of approximately 2 db is found. Since this volume change is barely audible, it is the practice of some studios now using this sound film to intercut prints made on *1372* out-take negative film with prints made on *1302*. In at least one instance, for the sake of uniformity of quality level, the sound department has requested the laboratory to purchase *1372* for use as a print stock for sound daily and rerecording prints instead of the customary *1302*.

TYPE 1373—FOR VARIABLE-DENSITY SOUND RECORDING

Advantages.—Just as improvements in sound recording equipment and technique have been many and rapid within recent years, so has it become increasingly evident that films for recording purposes must be designed to do the best possible job under the particular set of conditions which the sound engineer intends to impose upon them. This means that the older types of variable-density sound recording films, which were designed by the emulsion makers originally as either print stocks, or high gamma infinity dual-purpose sound recording films, have been found lacking.

Type *1373* emulsion differs from the older Eastman films which are used for variable-density sound recording in 2 primary respects: (*1*) It is finer grained and is thus capable of higher resolution and produces less background noise. (*2*) It is an inherently low gamma infinity emulsion, and has a considerably slower developing rate than other variable-density sound recording films.

A number of practical benefits derive from the second primary advantage mentioned above. They are:

(*1*) Marked reduction in directional effects.

(*2*) Elimination of special low-energy developer; *1373* may be developed in picture negative developer.

(*3*) Use by the laboratory of developing machines having best agitation conditions for picture negative development, as well as for sound negative development. At present this is not possible in most laboratories.

(*4*) Greater latitude in development control, owing to the flat characteristic of time-gamma curve.

Emulsion Characteristics.—In Fig. 1 are given comparative sensitometric curves for *1357*, *1301*, and *1373* when these emulsions are all developed to a gamma value of 0.55. This value of gamma was chosen for all 3 films as being typical of Hollywood practice, when variable-density sound negatives are printed onto *1302* with ultraviolet light. When this practice is followed, it is found that 0.55 represents the average control gamma value on these 3 sound recording films. If white light printing is used, the required IIb control gamma value is about 0.35 to 0.40 for all 3 emulsions, and the relative positions of the curves in Fig. 1 remain unchanged.

Until the introduction of Type *1373*, all variable-density sound recording negative required development in special low-energy developers which allowed the development process to take place sufficiently slowly so that the low gamma values required would be obtained in from 4 to 8 min. If the same films, such as *1357* or *1301*, were developed in regular picture negative developer, it was found that generally the minimum gamma value obtainable, with the developing machine speed set at maximum, was considerably higher than even the value of 0.55 required for ultraviolet printing.[5] Further, if the machine thread-up was so altered that the required gamma values could be obtained, it was found that the developing time under such conditions was of the order of 2 to 3 min, which is unquestionably too short for uniform development of a sound recording film.

At present at least 6 major Hollywood laboratories maintain such low-energy developers, primarily for the purpose of developing variable-density sound negatives. Referring again to Fig. 1, the curves for *1357* and *1301* were obtained by developing these films for 7 and 6 min, respectively, in a typical Hollywood variable-density sound negative developer, while the curve for *1373* was obtained by developing this film for 6 min in a typical Hollywood picture negative developer.

Fig. 6 shows a family of sensitometric curves, as well as time-gamma and time-fog curves obtained on *1373* in a normal picture negative developer under machine conditions considered to be about average in Hollywood. It is of interest to note the relatively small variation in gamma which accompanies a large variation in developing time. This is of considerable aid to the laboratory man whose problem is the maintaining of an exact gamma value from day to day on the sound negative stock. It is suggested that 4 times normal exposure be used in making control strips on the IIb sensitometer on *1373*, so as to obtain a full scale of density values.

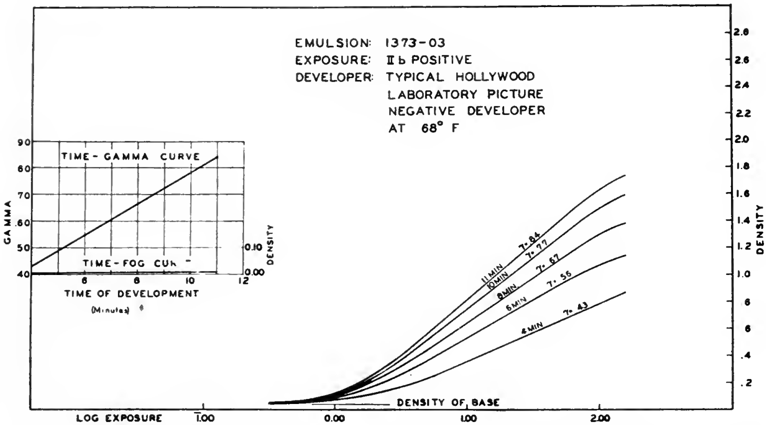


FIG. 6. Sensitometric curves of Eastman Fine-Grain Sound Recording Film, Type *1373*. Typical Hollywood processing conditions, picture negative developer.

In those cases where low gamma values, such as 0.35 to 0.40, are required for white light printing, it is apparent that the developing time of *1373* in picture negative developer may become impracticably short. In some laboratories, where the lower limit of developing time in their picture negative machines is too high to permit obtaining such low gammas on *1373*, it would then be necessary to use the variable-density sound negative developer. Typical sensitometric results obtained in such a developer are shown in Fig. 7. Tests made with *1373* emulsion have shown that there is no valid reason for objection to the use of the low-energy sound negative developer so far as sensitometric considerations are concerned. At equivalent gamma values, the densities obtained in the sound negative and picture negative developers are very nearly equivalent in several laboratories where such tests have been made. Likewise, the curve shapes are

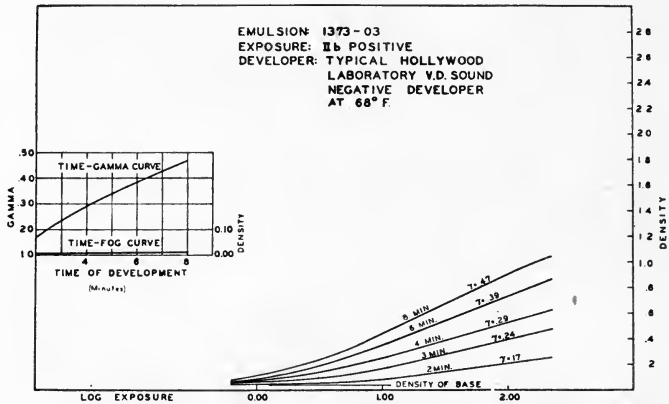


FIG. 7. Sensitometric curves of Eastman Fine-Grain Sound Recording Film, Type *1373*. Typical Hollywood processing conditions, variable-density sound negative developer.

identical within limits of experimental error. Formulas of the developers used for obtaining the data in Figs. 6 and 7 are given in Table 3.

TABLE 3

Developers Used for Variable-Density Sound Recording Films

Chemical	Picture Negative Developer	V.-D. Sound Negative Developer
Elon	2.7	0.26
Hydroquinone	1.5	0.21
Sodium sulfite, des.	70.0	32.5
Potassium bromide	0.1	0.2
*p*H	8.5	9.1

All quantities expressed as grams per liter of solution.

It is well known that the Eberhard effect, which manifests itself in motion picture film development as a "directional effect," is the greatest for moderate degrees of development, diminishes when the development is prolonged, and becomes negligible as the development approaches the limit. In other words, approach to gamma infinity permits the development of those areas which may have lagged because of excessive concentration of reaction products during the first and intermediate stages of development to catch up. As pointed out by Ives and Jensen,[6] Leshing, Ingman, and Pier,[7] and others, the lack of density uniformity because of the streaming of reaction products from contiguous areas in a variable-density sound track may be pronounced even with a reasonable degree of agitation. There is no other case in the processing of motion picture films where the develop-

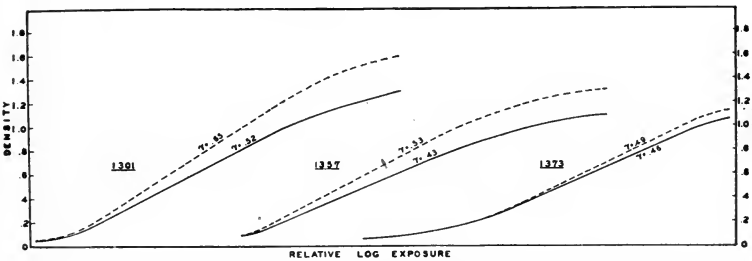


FIG. 8. Directional effect on several variable-density sound recording films. —— Regular IIb sensitometric step-tablet. - - - - - Dots, 2.4-mm diameter, 1 cm apart.

ment process is stopped so far from completion. The need for a variable-density sound recording film with inherently low gamma infinity which could, therefore, be developed so that the Eberhard effect is negligible, was obvious.

Leshing and Ingman[8] have employed the method of comparing densities of small dots with densities of large, contiguous areas, both having been given the same exposure, in order to study the degree of agitation in a developing machine. This same technique lends itself admirably to the comparison of various sound recording films under the same conditions of development. In Fig. 8 are given the characteristic curves obtained upon *1357*, *1301*, and *1373*. All these films except *1373* are of the inherently high-gamma infinity type. Along with normal IIb sensitometric curves, which are obtained by reading areas of increasing density approximately one centimeter square, are given curves obtained from the readings made on small circles of density, 2.4 mm in diameter with relatively large unexposed areas between steps. It will be noted that the spread between the pairs of curves is abnormally large in the case of the high gamma infinity films and very much less for *1373*. These data were obtained under actual working conditions in a Hollywood laboratory. Development time was 6 min for all films, with machine speed and agitation conditions identical, and the only variable, other than emulsion type, was the developer formula. In order that a reasonable match in gamma values be obtained, picture negative developer was used for the other films. It is believed that the difference in composition of the 2 developers used in making this test can account for very little of the difference found in directional effect.

Similar tests to those shown in Fig. 8 were made in other Hollywood laboratories. These tests lead to the following conclusions:

(*1*) Under conditions of actual laboratory practice, with differences in machine agitation, developing time, and developer formula, emulsion *1373*, in all cases, showed very much less directional effect than did the other 3 emulsions tested.

(*2*) The magnitude of the directional effect illustrated in Fig. 8 is fairly representative of conditions in Hollywood. Some laboratories had sufficiently good developer agitation so that the spread between the curves was very much less than that shown here. Other sets of data showed the presence of more directional effect than is evident in Fig. 8.

(*3*) The results of such tests depend strongly on the manner of reading test strips. Investigation showed that even a 2.4-mm diameter dot of fairly high density showed a considerable change in density if scanned across its diameter in the direction of film travel, providing it was developed in a machine with relatively poor agitation. Consequently, the dot densities reported here are the readings of the leading edges, and, therefore, the maximum densities of the dots when scanned with a viewing aperture, square in shape, and 0.62 mm on an edge. The Western Electric *RA1100A* densitometer with visual filter and a specially adapted aperture was used for these density readings. Tests made with larger dots of diameter 4.8 mm showed that a single dot of such size on a high gamma infinity film showed a variation in density across its diameter in the direction of film travel of from 1.12 to 1.37, while *1373* showed a variation of from 1.21 to 1.28. It is obvious that such lack of uniformity will not be encountered in scanning a single density step in a IIb sensitometric tablet, for the reasons that this step has other steps adjacent to it which tend to erase the large variation found in a small area of high density immediately surrounded by clear film. However, in a variable-density sound track, it is likely that alternate areas of such size and density difference do occur, so that wave-form distortion would be extremely great in the case of a high gamma infinity film coupled with poor developer agitation. Emulsion *1373* will do much to alleviate this condition even under the poorest conditions of agitation. Incidental to the more general problem, this property of *1373* will greatly aid in the elimination of sprocket-hole modulation.

The developed *1373* image has been found to have a lower color coefficient than other sound films, and the change in image color with increase in degree of development is less for *1373* than for other films. This is believed to be a result of the proximity to gamma infinity attained in ordinary development of this film.

In the past it has been felt necessary to have a sound film that was capable of being developed to a high gamma so that the short ends and out-takes could be used for prints. Many people have believed, however, in so doing the best results for the purpose for which the film was designed, namely, sound recording, were not obtained. The results obtained with Type *1373*, which is not capable of being developed to a high gamma, bear out that contention.

Type *1373* emulsion is very much finer grained than *1301* or *1357*, and is correspondingly slower in emulsion speed. It has been found

FIG. 9. Spectrogram of *1373* to tungsten light.

by comparison tests, however, that *1373* requires less exposure in the sound recorder at conditions of normal use than any previous fine-grain sound recording emulsion.

The color sensitivity of *1373* is shown in the wedge spectrogram in Fig. 9. This film, being blue-sensitive only, may be safely handled under a Wratten series *O* or *OA* safelight.

Emulsion *1373* is coated on a clear base, of the same type as used for emulsions *1357*, *1301*, and *1302*. It is available in 16-mm width on acetate base, and carries the code number *5373*. It is believed that this film will find widespread usage in the 16-mm variable-density recorders now being put into use by the motion picture industry for rerecording 35-mm feature pictures for subsequent 16-mm release.

Type *1373* film has the same over-all thickness as other variable-density sound recording films. Likewise, the emulsion thickness is about the same as *1357* and *1301*. Nevertheless, it is suggested that focusing tests be made for maximum resolution when this emulsion is compared with others, since it has been observed that this usually achieves a slight gain in high-frequency response.

Sound Quality Test Results.—Light valve gamma measurements, as well as high-intensity sensitometric curves made in the manner previously described in reference to *1372*, are shown for emulsion *1373* in Fig. 10, along with a IIb curve which was given the same development. The light valve gamma curve was obtained by changing the bias on the light valve by measurable amounts. The difference in mercury arc and tungsten exposure characteristics at high intensity is slight. The IIb control gamma matches the light valve gamma for this emulsion. This has been confirmed by other tests at lower and higher values of gamma. Since the absolute values of ex-

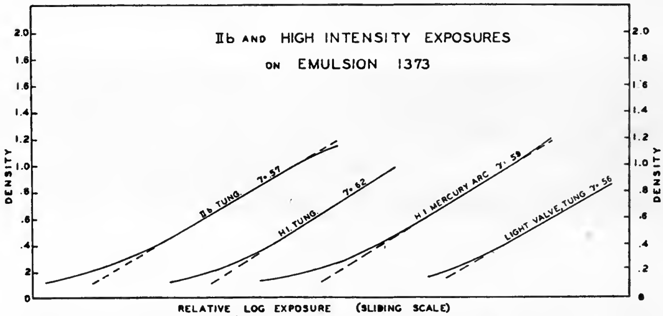


FIG. 10. Characteristic curves obtained on emulsion *1373* with various types of exposure. All exposures received the same development.

posure for the high-intensity curves are not known, the relative spacing of these curves on the log E axis is not significant.

Emulsion *1373* shows improved high-frequency response when compared with *1301* or *1357*. The signal-to-noise ratio is higher by approximately 6 db for *1373* than for *1301*. These advantages are to be expected of a film capable of higher resolution.

The intermodulation curves given in Fig. 11 were obtained by recording at a peak modulation of 2 db below valve clash, which is equal to approximately 80 per cent modulation. The 1000-cycle note was recorded at a level 12 db lower than the 60-cycle note. The numerical value of the minimum distortion is a function of the type of analyzer circuit used in making the measurements. The low levels of intermodulation distortion, such as those shown in Fig. 11, are believed to be as much the limiting values obtainable with the recording and analyzing equipment itself, as they are indicative of the film behavior. The latitude of print densities which can be used with a reasonably low value of distortion has been widened by the use of *1373*.

It is known that the required value of negative IIb gamma for minimum intermodulation at fixed negative and print density levels

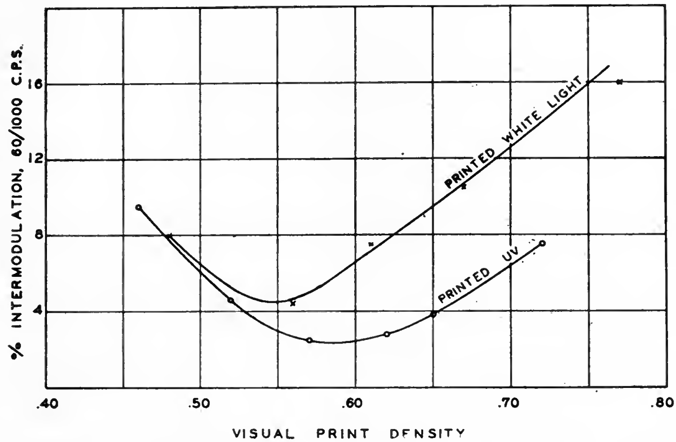


FIG. 11. Intermodulation as a function of print density. Eastman Fine-Grain Sound Recording Film, Type *1373*. Standard 100-mil track, recorded in W E *100 AA* recorder, 9.0-amp lamp, no filter.

	White Light Prints	U V Prints
Negative emulsion	*1373–01*	*1373–01*
IIb gamma	0.39	0.53
Unbiased density	0.57	0.56
Exposure (lamp current)	8.6 amp	8.0 amp
Positive emulsion	*1302–362*	*1302–362*
IIb gamma	2.40	2.40
Exposure	Tung.	Tung. + 2 mm Corning *584* filter

varies considerably with laboratories. This may be traced, in part, it is now believed, to the large differences in developer agitation at the various laboratories. This is equivalent to stating that the IIb control gamma does not bear the same proportionate relationship to the effective intermodulation test negative gamma at one laboratory as at another. This point will require direct proof, but is indicated by such data as presented in Fig. 8.

The authors express appreciation for the many helpful suggestions and test data supplied by the personnel of studio sound departments too numerous to mention by name. Especial thanks are due Robert Hufford who prepared the diagrams used in this paper.

REFERENCES

[1] DIMMICK, G. L.: "Improved Resolution in Sound Recording and Printing by the Use of Ultraviolet Light," *J. Soc. Mot. Pict. Eng.*, **XXVII,** 2 (Aug., 1936), p. 168.

[2] SANDVIK, O., AND SILBERSTEIN, G.: "The Dependence of the Resolving Power of a Photographic Material on the Wave Length of Light," *J. Opt. Soc. Amer. and Rev. of Sci. Instr.*, **17** (Aug., 1928), p. 107.

[3] MEES, C. E. K.: "The Theory of the Photographic Process," The Macmillan Co. (New York), 1942.

[4] O'DAY, D.: "Comparison of Variable-Area Sound Recording Films," *J. Soc. Mot. Pict. Eng.*, **45,** 1 (July, 1945), p. 1.

[5] FRAYNE, J. G., AND PAGLIARULO, V.: "The Effects of Ultraviolet Light on Variable-Density Recording and Printing," *J. Soc. Mot. Pict. Eng.*, **XXXIV,** 6 (June, 1940), p. 614.

[6] IVES, C. E., AND JENSEN, E. W.: "The Effect of Developer Agitation on Density Uniformity and Rate of Development," *J. Soc. Mot. Pict. Eng.*, **XL,** 2 (Feb., 1943), p. 107.

[7] LESHING, M., INGMAN, T., AND PIER, K.: "Reduction of Development Sprocket-Hole Modulation," *J. Soc. Mot. Pict. Eng.*, **XXXVI,** 5 (May, 1941), p. 475.

[8] LESHING, M., AND INGMAN, T.: "Some Turbulation Characteristics of New Twentieth Century-Fox Developing Machine," *J. Soc. Mot. Pict. Eng.*, **44,** 2 (Feb., 1945), p. 97.

DU PONT FINE-GRAIN SOUND FILMS—TYPES 232 AND 236*

HOLLIS W. MOYSE**

Summary.—*A description is given of the characteristics of 2 new du Pont fine-grain sound films. Type 232 is a positive used for white-light printing in conjunction with high gamma variable-density sound track negatives. Type 236 is a fine-grain recording negative film adaptable to both low and high gamma variable-density sound recording techniques.*

Standard practice for the majority of the variable-density recording system users had been, for several years prior to January 1, 1945, to print all production and release tracks with ultraviolet light. All controls and techniques had been standardized on this basis and millions of feet of high gamma sound and music negatives had been accumulated in libraries.

The decision of several of the studios to discontinue ultraviolet printing as of the above date affected all phases of sound production: dailies, dubbing, and release. In addition, it posed the question of what to do with the extensive library material that required ultraviolet printing when used in combination with normally processed fine-grain positive films.

A survey of the general situation indicated that there was no alternative to reducing the contrast of the release negative to compensate for the increase in printing contrast with white light. However, all production negatives could be kept at the standard "high" gamma level and the library question could be solved if fine-grain white-light prints of suitable contrast could be made conveniently.

Although fine-grain release positive processed in picture negative developers met contrast requirements, this approach was ruled out by practical laboratory considerations.

Appreciating the urgency of the situation, the du Pont Company undertook to make available a fine-grain positive film which, when

---

* Presented May 17, 1945, at the Technical Conference in Hollywood.

** Photo Products Dept., E. I. du Pont de Nemours and Company, Inc., Hollywood.

processed under standard release print conditions, would duplicate closely the effective contrast of ultraviolet printed fine-grain release positive.

Fortunately, much earlier tests had shown that the well-known du Pont Type *228* fine-grain master positive emulsion had approximately the desired effective contrast in positive developers, and could meet emulsion speed, signal-to-noise, and other criteria, very satisfactorily. This emulsion, with minor changes, was therefore made available to the industry in December, 1944, as a fine-grain sound positive under the type number *232*.

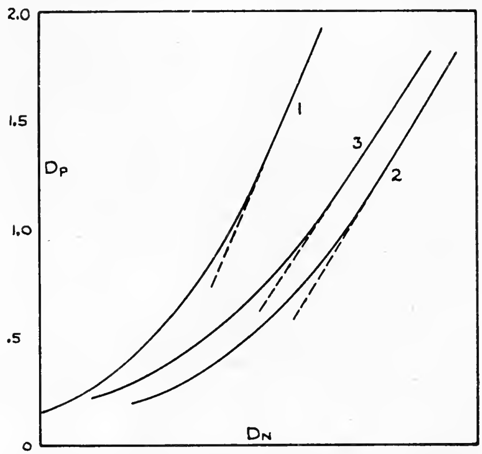


Fig. 1. (*1*) Type *225* white-light print; gamma = 2.30. (*2*) Type *225* ultraviolet print; gamma = 1.55. (*3*) Type *232* white-light print; gamma = 1.50.

Current practice in the studios effected by the change in printing technique is to develop all variable-density production negatives to the same contrast level as had been used for years with those intended for ultraviolet printing, and to make all daily, dubbing, and library prints with white light on Type *232*. Laboratory processing of these prints is identical with that given fine-grain release prints.

The close agreement in contrast and curve shape between ultraviolet printed released positive and white-light printed Type *232* is shown in the print-through-gamma curves of Fig. 1. These are not placed in their respective log E positions but serve to illustrate the point. They show also the extent of the contrast decrease obtained with ultraviolet printing of fine-grain release positive Type *225*.

Rate of Development of Type 232.—The time-gamma characteristics of Type *232*, as processed by a representative Hollywood laboratory, are illustrated in Fig. 2. It will be noted that the rate of change of gamma with time is low, a factor which favorably influences not only the accuracy of control but, more important, the extent of 96-cycle modulation and associated development effects.

Intermodulation tests, using the methods of Frayne and Scoville,[1] have been employed to determine optimum control gamma values for Type *232* and, as will be shown later, for Type *236*. The negative used in all cases, is a single track on which a 60–1000-cycle signal has been

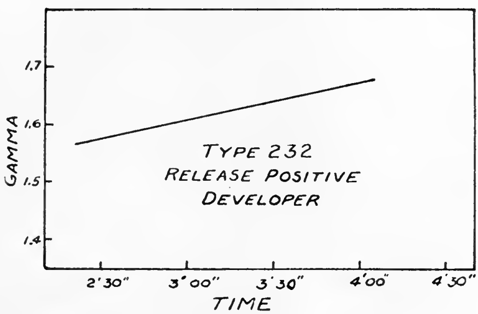


Fig. 2.

exposed in a Western Electric *D86715* recorder with 80 per cent modulation of the light valve.

Such tests, using a high gamma negative with white-light printing, have indicated a control gamma of approximately 1.6 as most suitable for Type *232*. This value is readily obtainable in release positive developers.

Intermodulation curves, such as shown in Fig. 3, indicate the distortion and print density latitude to be at least the equivalent of the best obtainable from ultraviolet prints from the same class of negatives made on fine-grain release positive.

No accurate data are available at the present time on the signal-to-noise ratio of Type *232* white-light prints, but the experience of several months in production has shown them to be definitely quieter than ultraviolet prints on fine-grain release positive. Some of the overall improvement may be a result of reduced image graininess, but a substantial proportion originates from their carrying appreciably less printed-through dirt and abrasion noise from the negative. Regarding the latter, all evidence points to the primary factor being the change in printing light color rather than to optical or mechanical alterations in the printing machines. The reduced noise level in Type *232* dubbing prints, of course, carries through to the final release product as a definite improvement.

Comparative frequency response measurements show a minor advantage of less than 1 db at 7000 cycles in favor of ultraviolet printed release positive.

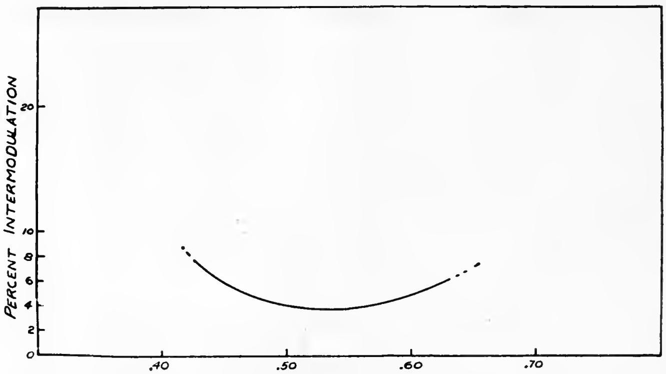


Fig. 3. Negative: Type *226*, gamma 0.85, density 0.55. Print: Type *232*, gamma 1.63.

In considering the release print phase of the shift from ultraviolet to white-light printing, it was obvious that the contrast of the release negative would have to be lowered to compensate for the increase in contrast encountered with white-light printing. Intermodulation tests indicated approximately a 30 per cent decrease in negative control gamma which, for a given negative density, required more than a one-ampere increase in recorder lamp current.

Du Pont Type *226* fine-grain recording film, designed originally for high gamma recording purposes, proved too low in emulsion speed to meet the new requirements when used in standard variable-density recording equipment. Therefore a second and more sensitive fine-grain recording film, Type *236*, was made available prior to the time of the studio change in printing methods.

Careful consideration was given in its design to both low and high gamma recording requirements. The emulsion speed, for example, was made just sufficient for low gamma recording purposes so that grain noise might be held to minimum values. Contrast factors were adjusted for convenient operation in developing solutions already available in Hollywood laboratories.

Development Characteristics of Type 236.—Fig. 4 shows a IIb and 2 time-gamma curves for Type *236*, as processed in a Hollywood laboratory which employs an MQ developer similar in formula to the du Pont *ND4*.

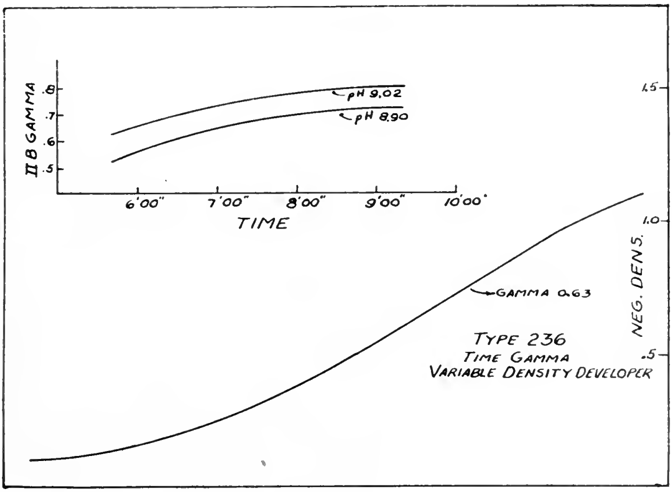


FIG. 4.

The lower of the 2 time-gamma curves is representative of the laboratory's standard operation and shows a low rate of change of gamma with time; this is insurance of minimum 96-cycle modulation and other undesirable development effects.

The upper curve illustrates the effect on Type *236* of an 0.12 increase in the *p*H of the formula—a simple and effective means of adjusting the activity of this class of MQ developers.

Intermodulation tests on the release combination of low gamma Type *236* negative, white-light printed to fine-grain positive, have indicated that a negative control gamma of approximately 0.65 is required with the standard Western Electric *D86715* recorder. This seemingly high gamma value is explained by the fact that the actual light-valve gamma is appreciably lower than the control gamma.

Light-Valve and IIb Characteristics of Type 236.—A comparison between light-valve and IIb sensitometric exposures on Type *236*, given identical processing, is shown in Fig. 5. The gamma of former is 0.47 and of the latter, 0.63. The relationship between light-valve and IIb gammas is so constant that the latter can be used satisfactorily for all control purposes. However, recorder optical arrangements can affect the gamma differential; this should therefore be checked either by light-valve or intermodulation tests for each type of recorder.

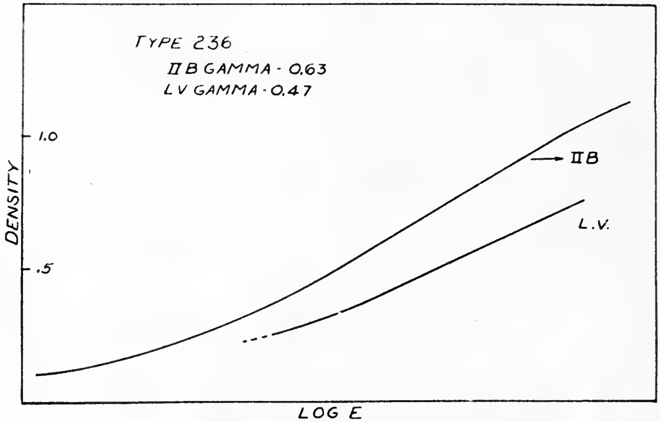


FIG. 5.

Intermodulation from White-Light Print on Type 225.—A representative intermodulation curve for the release combination of Type *236* white-light printed to Type *225* release positive is shown in Fig. 6. Satisfactory distortion values and good printing latitude are indicated.

Critical listening tests, which effectively integrate factors such as frequency response and signal-to-noise ratio, have established that no loss in sound quality has accompanied the change to white-light release printing with Type *236* employed as the release negative.

Type *236* has not as yet been applied extensively to production recording at high gamma levels wherein it would replace the standard Type *226*. However, data indicate that it is fully the equal of the latter in respect to distortion and print latitude and that, because of a lower rate of development, it will show appreciably less 96-cycle modulation if processed under conditions of poor developer agitation.

Intermodulation from White-Light Print on Type 232.—An intermodulation curve for Type *236* at high gamma levels, white-light printed to Type *232*, is shown in Fig. 7. Distortion and print latitude characteristics are fully as good as in the other combinations covered earlier.

It can be admitted now that the prospect of returning to white-light printing of variable-density negatives was not viewed optimistically when first considered. This was quite natural, since intermodulation records from the period prior to the change-over to

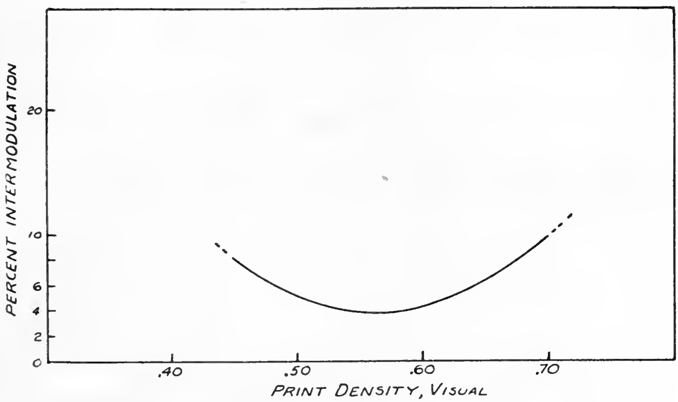


Fig. 6. Intermodulation from white-light print on Type *225*—Negative: Type *236*, gamma 0.64, density 0.52. Print: Type *225*, gamma 2.30.

ultraviolet printing showed distortion values several-fold as great as with the more recent ultraviolet printing of fine-grain films. These data, however, were based on the relatively coarse-grained recording and printing films of that period and have been proved unnecessarily alarming by the original tests and months of production experience with the white-light printed combinations of du Pont Type *232* and *236* fine-grain sound films.

Intermodulation of Release Prints.—Intermodulation curve *3* of Fig. 8 is representative of current release practice wherein a Type *236* low gamma negative is white-light printed to Type *225* release positive; it is essentially identical in distortion and latitude with the curves shown earlier for the other white-light printed combinations of the new films. Comparison of curve *3* with curve *2*, which is representative of high gamma negatives ultraviolet printed to the same release positive, shows an advantage to the former in both dis-

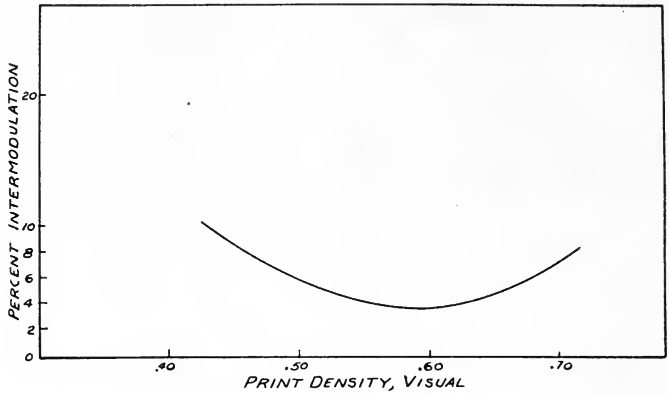


FIG. 7. Intermodulation from white-light print on Type *232*—Negative: Type *236*, gamma 0.76, density 0.63. Print: Type *232*, gamma 1.55.

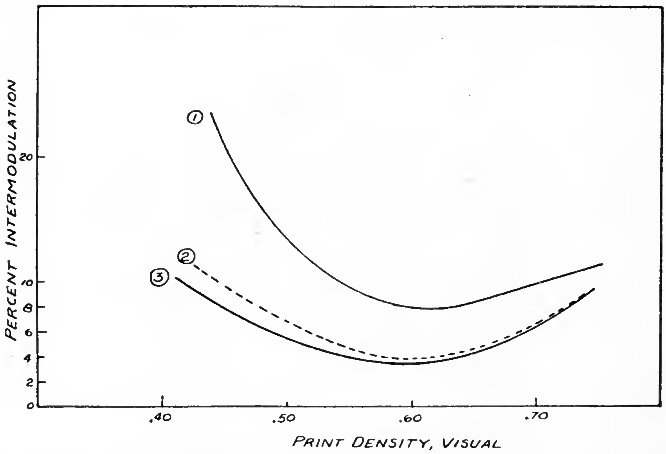


FIG. 8. Intermodulation of release prints. Curve (*1*): Old-type recording and positive films printed with white light. No data. (From Frayne and Scoville.[1]) Curve (*2*): High gamma negative printed with ultraviolet. Negative: Type *226*, gamma 0.64, density 0.55; Print: Type *225*, gamma 2.30. Curve (*3*): Low gamma negative printed with white light. Negative: Type *236*, gamma 0.64, density 0.52; Print: Type *225*, gamma 2.30.

tortion and print latitude, particularly in the useful low print density region.

Curve *1*, from the paper of Frayne and Scoville,[1] may be considered as representative of best practice with the old-type recording and positive films, white-light printed, and is included as a matter of interest to show the extent of the improvement obtained with fine-grain films.

It may be said, in conclusion, that the change from ultraviolet to white-light printing has been effected without loss in sound quality or in facility of operation with the assistance of du Pont fine-grain sound films, Types *232* and *236*.

REFERENCE

[1] Frayne, J. G., and Scoville, R. R.: "Analysis and Measurement of Distortion in Variable-Density Recording," *J. Soc. Mot. Pict. Eng.*, **XXXII**, 9 (June, 1939), p. 648.

THE U. S. NAVAL PHOTOGRAPHIC SERVICES DEPOT*

FANNING M. HEARON**

Summary.—*A brief description is given of the establishment and activities of the U. S. Naval Photographic Services Depot in Hollywood. The Depot serves as the production center for all of the Navy's motion picture training films made on the West Coast.*

The U. S. Naval Photographic Services Depot, at 1357 North Vine Street in Hollywood, California, is the West Coast station of the Photographic Division of the Navy's Bureau of Aeronautics. It was established on June 23, 1943, by the late Secretary of the Navy Frank Knox. Prior to that the Navy's then limited Hollywood activities had been conducted from offices in the Disney Studios.

The depot is charged with handling all of the Navy's picture business on the West Coast, with emphasis on the Hollywood area. Its largest responsibility is the production of training films for the bureaus and commands of the naval establishment. These pictures are produced by the major studios, by the animation and model people, by the small independents who made business films in peacetime, and by Navy and Marine Corps camera units.

The production load has been averaging around 100 films. In 1944 the station completed 96 pictures, many of them as complicated as theatrical features. The activity's officer-in-charge refers to his station as "the feature department." Thirty-one of these were produced from script to screen by Navy and Marine units in 31 weeks. The subjects were the facilities, doctrine, and personnel of amphibious warfare.

The major studios produce for the Navy at the actual cost of doing the picture. The animation and model studios and the business film producers receive from 7 to 10 per cent profit, plus overhead. The Navy and Marine crews produce for just what it costs to keep them

---

* Presented May 17, 1945, at the Technical Conference in Hollywood.

** Lieut. Commander, USNR, Officer-in-Charge, U. S. Naval Photographic Services Depot, Hollywood.

going. This military personnel production is averaging $1.55 per ft, a figure which has held for government-employee picture making for many years. The 4 camera crews functioning at the depot usually are reserved for highly classified, high priority projects, involving a volume of naval personnel and equipment. Usually these pictures, which must be completed and released in a few weeks, are concerned with new weapons and doctrines of modern warfare.

The majors get the "features," the 6 or 8 reelers requiring extensive production, usually the indoctrination or "attitude establishing" type of film. The little independents take on the simpler jobs, and the animation-model people get the animation and the models. If a film being made by a studio contains sequences which call for authentic background material which can be shot only on location at some naval establishment, these sequences will be assigned to Navy camera crews. If desirable, the studio director will take over the Navy crew and cut in the sequences after completion of the studio footage.

By virtue of a unique contract with Paramount Pictures, the station's Navy camera crews have access to the stages and facilities of that company. And the local labor groups have cooperated in working side by side with men in uniform.

Production jobs are assigned to the station at various stages. Some bring no more information than the title and the source of technical advice. Others come as production outlines, and others arrive as completed scripts. Nearly all writing is done by personnel of this depot. No project is taken to a major studio except in shooting script form. That is the way they like it.

The station maintains a procurement section which solicits production proposals from producers and gets the budgets in proper form prior to sending to Washington for processing and final approval. This procedure has eliminated much production delay.

Production is the depot's number one activity, but there is some distribution of color prints and prints which must go direct to the fleet or West Coast shore establishments. Certain special services also come into the picture. These may include repair of projection equipment or cameras for a ship or shore facility, experimental photography, shooting a few hundred feet on some rocket test for Cal. Tech., the production of some localized short for a particular command, and many other odd jobs. Recently the station designed a wing camera which may well revolutionize the whole business of aerial photography.

The premises of the station include individual offices, a shooting stage, stowage and shipping quarters, 2 projection rooms, a still laboratory, Moviola room, art department, special effects department, and the inevitable coffee mess.

The personnel at the depot are largely from the motion picture industry. The current complement (increases have been requested) is 27 officers and 42 enlisted men, but there usually are around 100 persons aboard. The extras are photographic personnel and technical advisors on temporary duty. These technical advisors for the various types of films are among the Navy's most competent officers. They have studied their subjects, seen them in action, and now it is their job to get them on film so others may learn easily what they have learned the hard way.

AN OPTICAL CUEING DEVICE FOR DISK PLAYBACK *

GARLAND C. MISENER**

Summary.—*Described in this paper is an optical device of simple arrangement which serves to permit accurate placement of pickup stylus for a series of cues in photography to music playback from disk.*

Various applications of disk records and transcriptions are facilitated by the use of a cueing or spotting device which will enable accurate placement of the pickup stylus on the disk record. In fact, if extensive versatility is to be realized in the application of standard pitch disks to photography by playback, a highly accurate device for cueing is essential. Some musical productions involve continuous sequences of photography, in which live sound pickup with dialogue is alternated with playback of music from disk recordings. For example, such a sequence may start with introductory dialogue between vocalists, to be followed by playback music which must start precisely on a word cue. Then, with the camera continuing to cover the same scene, the vocalists may go directly from action with playback into live dialogue, followed by a cue for another vocal selection or dancing to playback. Still further alternations between live sound pickup and action to playback may follow in the same scene, requiring that the playback operator be able to start each playback section accurately on cue.

A number of cueing aids, ranging from simple marked strips of cardboard to rather intricate mechanical-electrical devices, have been made and used in radio and motion picture studios. Some of these devices have undoubtedly rendered satisfactory service in the application for which they were specifically designed. However, local requirements created the need for a device of simple construction which would permit operation with split-second cueing. It was desirable that this device should not involve attachments of appreci-

---

* Presented May 16, 1945, at the Technical Conference in Hollywood.

** Major, Signal Corps, Signal Corps Photographic Center, Long Island City, N.Y.

able weight to the pickup arm, nor should apparatus be installed over the turntable which would impede the handling of disks. Of prime importance was the requirement that the device enable pre-setting accurately as many cues as desired for a scene of photography, with reliable performance in order to preclude the necessity of retakes caused by errors in playback cueing. The construction was to be such that maintenance would not present a problem.

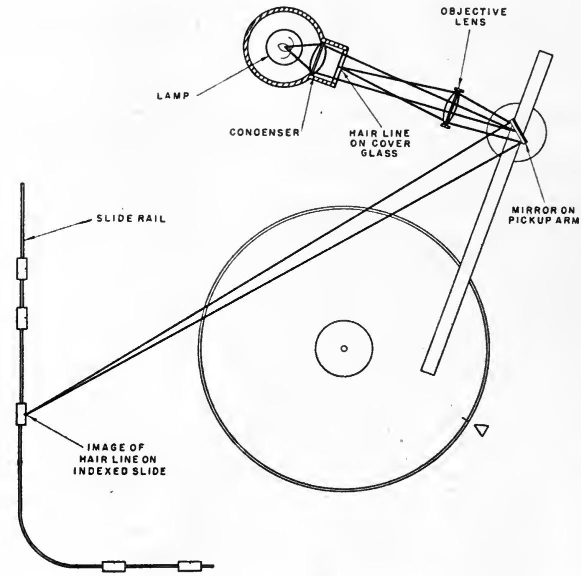


Fig. 1. Schematic plan view of arrangement of playback cueing device.

The arrangement arrived at and now in use is indicated in Figs. 1 and 2. The optical system is essentially that of certain variable-area recorders up to the point of the recording mask image on the slit. A one-ampere exciter lamp illuminates a hairline object, the latter being mounted on a cover glass in front of a condenser in the lamp house. The condenser images the lamp filament in a small mirror mounted on the pickup arm directly above its pivotal point. Mounted on a post near the pickup arm and mirror is a simple-element objective lens. This objective forms an image of the hairline on a slide and rail assembly at the opposite side of the turntable cabinet, with the beam reflected by the mirror in the image space. A single-element objective with a relative aperture of approximately $f/8$ provides sufficient image brightness, if the rail is shielded from spurious illumination.

As represented by the traverse of the hairline image, the lateral movement of the pickup stylus is magnified by a factor of two through the mirror reflection. The ratio of the slide-mirror distance to the stylus-mirror distance determines the additional magnification obtained. The total magnification in the units constructed is approximately five. For this factor and with a disk cut to a pitch of 100 lines per in., the hairline image will move 0.050 in., or 1.27 mm per revolution of the disk, an easily discernible increment. If the disk is

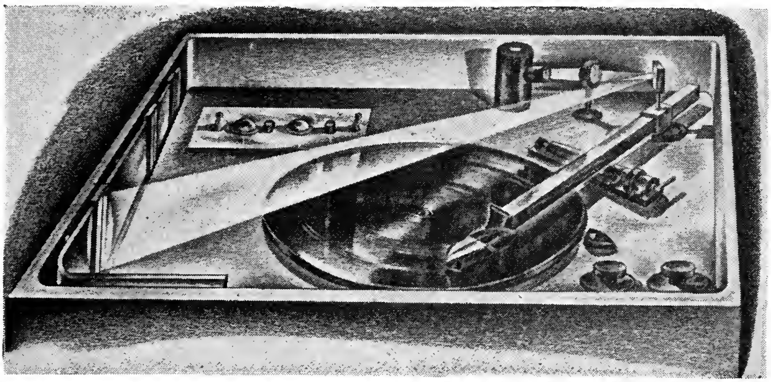


FIG. 2. Sketch showing light beam focused on slide index.

made on a recorder which has cutter feed error, the resulting eccentricity of the cut will produce a nonuniform motion of the hairline image. However, since each cue will be taken for a given angular orientation of the turntable, the eccentricity will cause no difficulty in using the device. This follows from the fact that for any given orientation of the disk, the increments of stylus traverse per revolution are essentially uniform.

In operation, the slides are set for each cue by running in while listening, and stopping the disk with the hand while a slide index line is aligned with the hairline image. The playback units are equipped with headphones so that the operator may pre-set the cueing device without disturbing the stage. Once the cues are pre-set, the operator may return to any one of them quickly and as many times as desired. This facilitates rehearsals in particular. The cues may be applied in various ways. For example, they may be used to indicate the points at which the playback signal is to be switched or faded, on or off, while the disk is running. In other cases, the cues may be used to indicate when the pickup is to be dropped to or lifted from the running disk. In still other instances, the disk may be held by hand, with the turntable rotating, and the pickup placed by aid of the cueing device. The disk is then released on an action cue from the stage.

To facilitate placement and release of the pickup arm, an auxiliary device is mounted under the pickup arm near the turntable, as shown in Fig. 2. This consists of a horizontal bar suitably mounted, which

Fig. 3. Photograph of unit in use at Signal Corps Photographic Center.

is raised and lowered by means of a hand-operated cam. Lateral adjustment of this bar support is provided by a thumbscrew. With this arrangement, the pickup arm may be placed on the bar so that the hairline image is approximately aligned with a slide index line. Then the thumbscrew is used as a vernier adjustment to secure exact alignment.

The device described is obviously simple in construction (see Fig. 3) and requires little maintenance, yet offers the advantage of allowing pre-setting for as many cues as may be necessary in a scene of photography to playback. There is nothing to obstruct changing or reversing disks, and the only apparatus attached to the pickup arm is a small mirror of inconsequential weight. The pre-set cues may be applied either with the disk in motion or held in position.

This arrangement suggests other variations which might be helpful in meeting special requirements. For example, the indexed slides might be provided with a slit, behind which a photocell or cells could be mounted for automatic activation of audio-control circuits or signal devices on the stage. In cases where space for projection of the hairline image is limited, adequate magnification of the stylus traverse may be obtained by placing a second mirror on a fixed mount near the mirror on the pickup arm. This will provide an additional factor of two in the magnification of the angular displacement.

DEVELOPMENT OF TWO AUTOMATIC FOLLOW-FOCUS DEVICES FOR USE IN CINEMATOGRAPHY*

JAMES T. STROHM AND WILLIAM G. HECKLER**

Summary.—*A description is given of the method devised by the authors and used at the Signal Corps Photographic Center to eliminate human error in critical focusing by automatic means. The fully-automatic dolly was designed primarily to eliminate these difficulties when the camera is in horizontal movement.*

In the course of producing training films at the Signal Corps Photographic Center, Long Island City, New York, it was soon realized by the cinematographers attached to the Camera Branch that, in many instances, the type of photography required for training films, orientation films, morale films, *etc.*, was somewhat different than the photography required for the production of entertainment films as normally produced in the major Hollywood studios. At the outset the production cameramen and special effects cameramen soon found that a great percentage of the Signal Corps productions required numerous shots of maps, diagrams, mock-up models, inserts, miniatures, *etc.* In so many shots of this type it was necessary to open the scene with a full shot of a map, diagram, or model, and then move the camera in to a specific point in order to call attention to it or emphasize it. The reverse of this procedure was also often the case, where it was necessary to open the shot at a specific point and then move the camera back in order to encompass the entire object.

Many difficulties were encountered in an effort to photograph such shots with the required degree of accuracy. First of all, the Camera Branch was hampered by having only a few highly trained and competent camera operators capable of operating the camera in these extremely difficult shots and also only a few assistant cameramen who had had enough experience in changing focus on lenses accurately. The procedure of accurately changing focus on a photograph-

---

* Presented May 16, 1945, at the Technical Conference in Hollywood.

** Captains, Signal Corps, Camera Branch, Signal Corps Photographic Center, Long Island City 1, N. Y.

ing lens while the camera is in motion is extremely difficult and requires a great deal of instruction and constant practice. It was found that inexperienced camera operators were never sure if the object being photographed was in sharp focus throughout the entire length of the scene, and it was always necessary to rephotograph the scene several times with the hope that one of the "takes" would be in sharp focus.

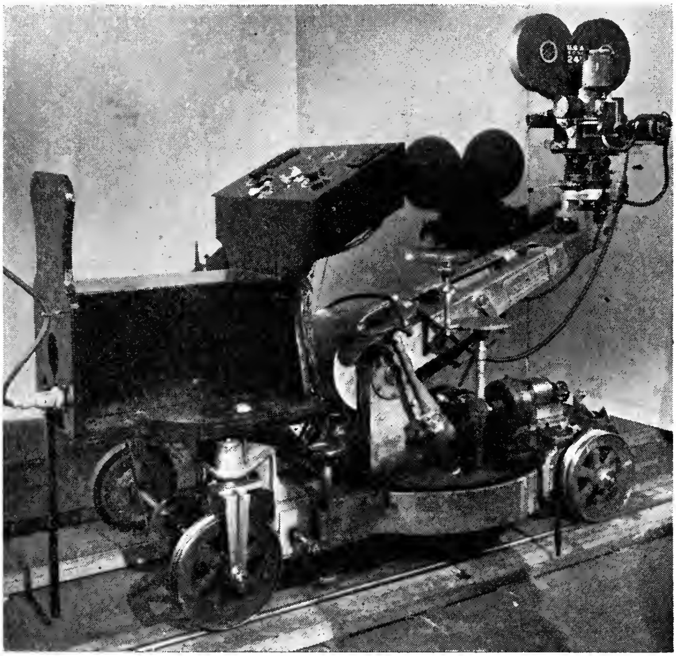


FIG. 1. Automatic dolly.

Difficulties were also experienced with camera dolly "weave" and vibrations, resulting from the human element introduced in starting and stopping the dolly and variations in the dolly tracks. For the same reason, acceleration surges were seldoma bsent. Also, accurate synchronization of in-and-out movements with up-and-down movements of the camera was seldom realized.

It soon became apparent that it would be advantageous to construct some sort of device which would eliminate the human element not only in moving the dolly but also automatically changing the focus of the photographing lens during the periods when the camera was in horizontal movement. Research work was begun to accomplish this end and resulted in the development of the present all-electric and fully automatic camera dolly which is used at the present time by the Camera Branch at the Signal Corps Photographic Center.

This fully automatic electric dolly is an adaptation of a standard Raby camera dolly. (See Fig. 1) The 2 standard rubber wheels are retained on the left side, while the standard rubber wheels on the right side have been replaced with 2 bronze wheels which have had a *V*-shape groove cut into their riding surfaces. Round $^1/_2$-in. tubings which are countersunk into a wooden base act as a straight-line guide for these wheels. Troublesome weave and vibrations are completely eliminated by this new combination of dolly guide wheels and track tubing. The track joints themselves are carefully butted together, eliminating the usual track irregularities.

The power unit which motivates the dolly consists of a $^1/_4$-hp, 110-v d-c motor which has a top speed of 1725 rpm. The shaft of the motor is connected to the speed reducer box by means of a rubber coupling that takes up all motor vibrations as well as start and stop jars. The speed of the d-c motor is reduced 50 times by the reducer box, and a sprocket gear pulley from it engages the sprocket chain which in turn rotates the dolly axle and bronze power wheel. A rheostat governs the speed control, while standard reversing switches determine direction.

Essentially, the same type of power unit has also been installed on the dolly and is applied to the dolly tilt arm so that it may be raised or lowered with ease even when the dolly is in motion. To the rear of the unit a seat for the dolly operator is provided, together with a control panel which contains switches and controls that govern the speed and movement of both the dolly and the tilt arm. The control panel also contains dials which show any given position of the dolly and the tilt arm. Once the dolly operator knows the conditions of the shot he can duplicate these conditions any number of times without fear of error, for any error that he might make would be plainly indicated on the control panel after the shot was completed. Also, additional switches make it possible for the operator to control the entire series of movements by the throwing of a master switch.

The most important mechanism installed on the dolly, however, is an automatic follow-focus device. As stated above, this device was developed and installed because of the great need for accurate and positive focus, particularly on close follow shots where the narrow depth of field characteristic of photographic lenses as they closely approach a given target demands extremely accurate focusing. This need was of particular importance in special effects work where follow shots are concerned mainly with extremely accurate framing and the extreme proximity of the lens to the object or target. Such examples can be cited as the need to move from a close-up of an individual to his mouth or eyes, or in some cases, to one eye. Another

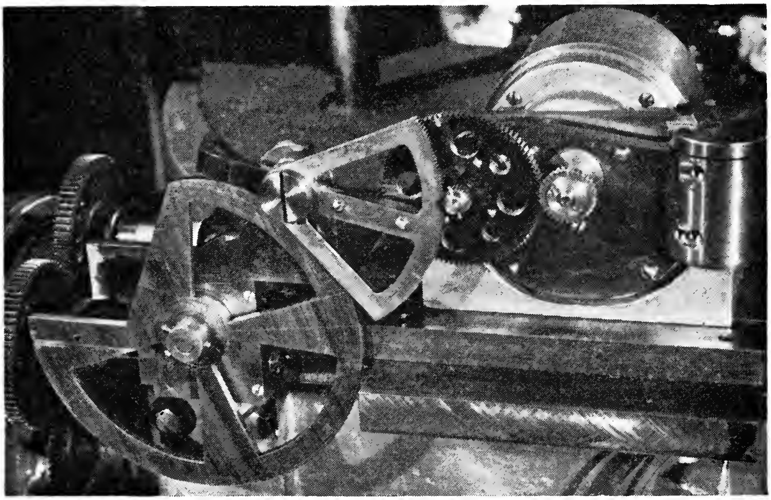


FIG. 2. Dolly cam and gear assembly.

common case could be cited such as moving up to or away from small sections of maps or titles.

Although this device could be used in many instances in standard set procedure, no intent was made to displace current production methods and it was conceived only for those highly difficult follow shots which are almost impossible to accomplish when the cameraman must depend upon the judgment of the operator or assistant to focus the lens by hand. The automatic focusing of the photographing lens is accomplished in the following manner.

The focus unit receives its activation from the right front dolly wheel. (See Fig. 2) It transfers this energy to a cam, which has a contour pitch, complementary to the curvilinear action of a 2-in.

lens or of the particular focal length lens desired. This action is applied to a small gear on the end of the shaft of a Selsyn generator motor. The rotation of this motor is transmitted to and received by a Selsyn receiving motor. A small gear, same size as on the generator, is mounted on the end of the receiving motor shaft. This activates a pinion gear, which turns the actual lens gear itself. (See Fig. 3)

There is a distinct advantage in using electrically connected Selsyn or interlock-type motors to transmit the movement of the dolly to the photographing lens. As can easily be seen, this does not restrict the movement of the camera in any way. The only connection between the receiver motor and lens assembly, and the motor which is activated by the cam and gear assembly, is a flexible cable containing only the motor wires. Hence, it can be seen that the camera may be tilted up or down or panned to right or left without any hindrance whatsoever.

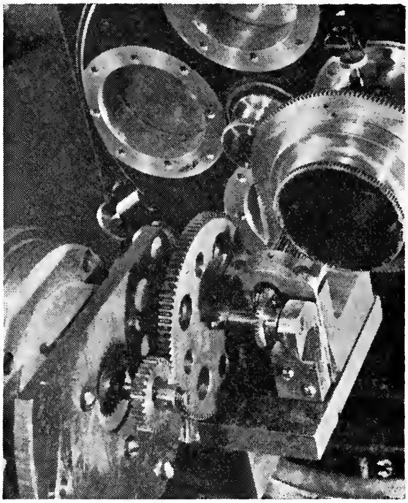


Fig. 3. Dolly lens gear assembly.

A standard Mitchell camera is used on the unit, which is equipped with a 50-mm Bausch & Lomb *Baltar*, $f/2.3$ lens in a standard Mitchell lens mount. To the lens mount a ring gear was mounted which is meshed with the control gear of the receiver motor assembly. The 50-mm lens can be focused automatically from 50 ft to 18 in. Within these limits, no matter where the dolly is moved or at what speed it is moved, the lens is always automatically held in sharp focus.

The benefits derived from this unit are numerous. One advantage of its use has been a great saving in both time and labor. Before the unit was in operation it was necessary to use as many as 6 men to complete a difficult follow shot. In some instances scenes of this nature required a camera operator, an assistant cameraman to change focus, one or 2 men to push the dolly, a fifth man to call out footage marks, usually marked on the floor, and possibly a sixth man to carry the camera motor cable back and forth as the dolly was moved. As mentioned before, the common practice was to photograph the scene many times hoping that at least in one of the "takes" all of the technicians connected with the scene had coordinated and synchronized their operations correctly. This, of course, required a great amount of time, an abnormal waste of film, and usually a crew of from 4 to 6 men. With the use of the automatic electric dolly most

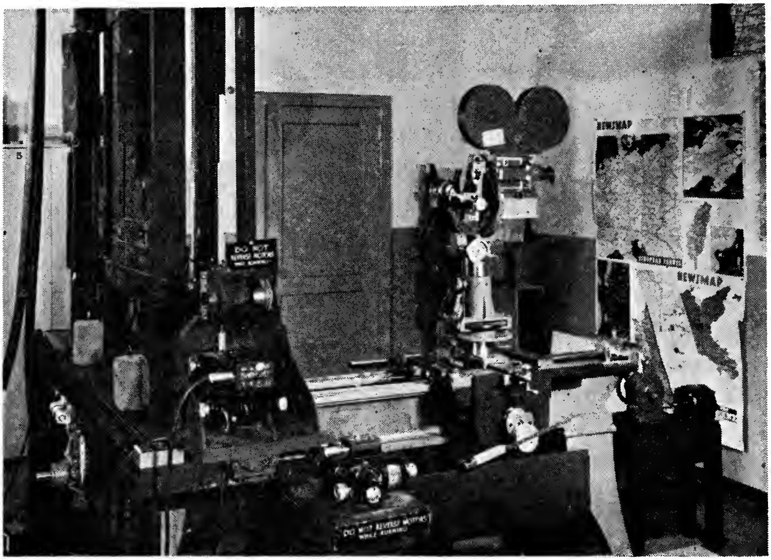


FIG. 4. Title and insert stand.

of these disadvantages were eliminated. No matter how difficult the scene the unit requires the use of only 2 men, the camera operator and the dolly operator. The only function of the camera operator is to start and stop the camera and to operate the pan and tilt head if this should be necessary. The dolly operator controls the movement of the dolly, and all other necessary operations are performed automatically.

Since the unit has been in use it has been found that there are few occasions where it is necessary to make more than one take of the scene. The saving in film because of this advantage can be recognized at once.

In conjunction with the development of the automatic follow-focus electric camera dolly, a similar device was developed to accomplish the same results on a permanently installed Insert and Title Stand. (See Fig. 4) In many cases it was found to be more convenient to mount certain maps, titles, and other special objects on a title board which was placed in an upright position and attached to a lathe bed. The camera was mounted on a movable pedestal which in turn was mounted on a smooth raceway. This raceway was substituted for the original lathe rack and constructed in such a way as to permit the camera to be moved back and forth on it. When the unit was put into use, approximately the same problems presented themselves as before. It was even more difficult to change focus accurately when moving the camera, for the shots made with this unit usually required a higher degree of accuracy both in focusing and framing. It was necessary to design the equipment in such a manner so as to allow the 3-in. camera lens to approach the title board or target as close as 12 in.

Because of the complex nature of certain shots, it was also decided that there would be a distinct advantage in being able to move the title board automatically in either a horizontal or vertical direction. To accomplish these features, the unit was reconstructed in the following manner.

The title board part of the installation is made to move in a horizontal and vertical direction by means of 2 Bodine speed reducer-type animation motors. One of these motors powers the horizontal movement, the other the vertical. The single frame feature permits small precise moves for straight or animation work. The reversing switches provide directional control. The speed adjustments allow speed control for board movements. Both motors are geared down by 12 to 1 reducer boxes. This smooths out the movements and gives proper basic speed. The follow focus is effected by mounting a contour strip, complementary to the linear movement of a 3-in. rack type of lens along the side of the lathe bed. A small ball-bearing roller makes contact with this contour. A shaft connects the roller bearing to the shaft of a Diehl-type Selsyn generator motor via reduction gears. The action of the ball bearing as it follows the contour strip activates the generator which electrically transmits identical turns to the receiving Selsyn motor's shaft. On the end of the shaft of this motor, a small gear engages and activates the rack and pinion gear directly attached to the rack lens mount itself.

In the actual practice of cinematography at the Signal Corps Photographic Center, both of these devices have been used with a great deal of satisfaction by the cinematographers who are charged with the responsibility of making these difficult shots. During peak periods of production they have enabled the Camera Branch to complete many different scenes of this type where formerly it was possible to complete only a limited number.

It is felt that this dolly with the automatic focus device could be very successfully utilized in television camera operation because of its remote control and pre-set switch features. Another suggested use for this unit would be in connection with rear projection or process photography where it might be advantageous to dolly the projector in or out during a scene.

The writers wish to express their appreciation to the Pictorial Engineering and Research Laboratory Division and the Central Machine Shop Branch of the Signal Corps Photographic Center for their cooperation and valuable assistance in the design and construction of these devices.

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

26 (Aug. 1945), No. 8

The Academy War Film Library (p. 261)	E. Goodman
A Crumbled Movie Empire (p. 262)	I. Browning
Films in India (p. 265)	F. Berko
Fades, Lap-Dissolves, and Other Tricks (p. 266)	R. Palmer
The Production of Scientific Films for Biological and Medical Purposes (p. 295)	J. Y. Bogue
Shooting Production Under Fire (p. 296)	H. A. Lightman
Cradle of American Cinema (p. 298)	I. Browning
Cine-Chronized Sound on Wire for Amateurs (p. 300)	L. Conway

Communications

25 (Aug., 1945), No. 8

Resonant Loudspeaker Enclosure Design (p. 35)	F. W. Smith

General Electric Review

48 (Sept., 1945), No. 9

Image Contrast in Television (p. 13)	C. H. Bachman

International Photographer

17 (Aug., 1945), No. 7

Movie Sound to Order (p. 13)	
Alton Improved Dolly Track (p. 14)	J. Alton
The Walker Comparison Meter (p. 18)	J. Walker
G. E. Flask Tube (p. 26)	

17 (Sept., 1945), No. 8

Photographing Air Routes and Installations (p. 9)	F. Crosby
Making 16-Mm Reduction Prints (p. 12)	S. A. Cohen
Visual Music (p. 19)	J. Alton

International Projectionist

20 (Aug., 1945), No. 8

EMPLOYMENT SERVICE

POSITIONS OPEN

Designer and engineer experienced in optics, lighting, and microphotography, capable of designing microfilm reading equipment and products related to microfilm industry. Reply to Microstat Corporation, 18 West 48th St., New York 19, N.Y.

Design engineer, experienced in mechanics and optics of motion picture cameras, projectors, and film scanning. Give details. Reply to Mr. John H. Martin, Columbia Broadcasting System, Inc., 485 Madison Ave., New York 22, N.Y.

POSITIONS WANTED

Sound recording engineer, 16- or 35-mm equipment, studio or location work, single or double system. Free to travel. For details write J. J. K., 354 Ninth Ave., New York 1, N.Y.

Honorably discharged veteran with 15 years' experience in all phases of motion picture production, including film editing, directing, producing. For details write F. A., 30-71 34th St., Long Island City 3, N.Y. Telephone AStoria 8-0714.

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

Director of visual training aids, now concluding government work, desires position with educational, industrial or commercial organization, supervising or assisting in the production or distribution of visual training or allied work. Write H. C. B., 348 Maryland Ave., Dayton 4, Ohio.

Chief Engineer of motion picture camera manufacturer now available. Special training in optics, electricity, electronics, mechanics. Experienced in all phases of manufacture of cameras, projectors, and accessories. Prefer West Coast, but not essential. Write Robert Winkler, 119 West 78th St., New York, N. Y.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 **NOVEMBER, 1945** **No. 5**

CONTENTS

Indexes to the semi-annual volumes of the JOURNAL are published in the June and December issues. The contents are also indexed in the *Industrial Arts Index* available in public libraries.

JOURNAL

OF THE

SOCIETY of MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA • NEW YORK 1, N.Y. • TEL. PENN. 6 0620

HARRY SMITH, JR., EDITOR

Subscription to nonmembers, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscription or single copies of 15 per cent is allowed to accredited agencies. Order from the Society at address above.
Published monthly at Easton, Pa., by the Society of Motion Picture Engineers, Inc.
Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, Hotel Pennsylvania, New York 1, N. Y.
Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 NOVEMBER, 1945 No. 5

MACHINE PROCESSING OF 16-MM ANSCO COLOR FILM*

J. L. FORREST**

Summary.—*Ansco Color 16-mm motion picture film has been manufactured for several years. The bulk of the production has been used by the Armed Forces. In field operations, hand methods of developing have been used. However, for first-class results an especially designed processing machine is recommended. Such machines have been constructed by Ansco and in this paper the author describes the design and use of these machines.*

The processing of color motion picture film has, in the past, been restricted to a relatively few laboratories specializing in this work. With few exceptions, most theater-length productions in color have been produced by dye imbibition processes. A similar method has been used for the production of most color cartoons.

Numerous special processes of dye toning, dye bleaching, *etc.*, have been proposed and some have been used for the production of short subjects. However, none of these has gained wide acceptance, probably because of the numerous complications associated with such procedures and the unpredictable results obtained by them.

Dye-coupling color processes, although not new, have come into prominence through advancements in organic chemistry which made their practical application possible. The Kodachrome process, introduced some 10 years ago, was the first dye-coupling subtractive color process to be carried out on a large commercial scale. It was confined for many years to the 16-mm field. Kodachrome developing has been carried out only in the laboratory of the manufacturer.

Agfacolor, another dye-coupling method, was introduced in 1936 or 1937 and gained some prominence before the war. Although the Agfacolor process was not as complicated as previous dye-coupling

---

* Presented May 17, 1945, at the Technical Conference in Hollywood.

** General Manager, Reversal Laboratories, Ansco, Binghamton, N. Y.

procedures, the developing formulas and procedures were not released to the public.

Ansco has been experimenting with multilayer, dye-coupling subtractive color procedures for many years. This research has been directed toward simplifying the color process to the extent that the developing would not have to be carried out by the manufacturer, but could be done in any well-equipped laboratory. Our process was nearly completed before the war. Through an intensified research program carried on because of war necessity, experimental work,

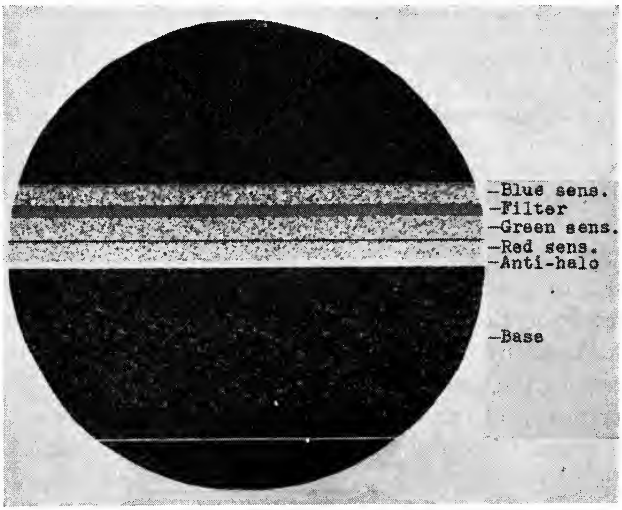


Fig. 1.

which would ordinarily take years, was reduced to months and the product was perfected.

Throughout the war, we have been supplying more and more color products for military needs. Some of these products are now also being made available to civilian trade in small quantities. While some of these products as they become available to the trade seem new, they are not new products to us for we have been making many of them since the beginning of the war.

We have been called upon to assist in processing these color products in all parts of the world and we have gathered a great deal of information on the product and its behavior under various processing conditions. As these products are converted from war needs to civilian needs, this information can be made available for civilian use. In addition to this, our laboratories in Binghamton, New York, have been processing the material for a number of years on modern processing equipment which I am going to describe.

Ansco Color Film is a multilayer film of the reversible type, producing color by subtractive synthesis. The over-all thickness of the film is the same as any ordinary negative film. In normal use, the film is exposed in the camera without filters of any kind. During exposure, the image is broken up into its color values by the multilayer emulsion.

TABLE 1

Processing Procedure for Ansco Color Film

Step		Time	Temperature
(*1*)	First Develop	12 min	68 F ± 1/2 degree
	Short Rinse	5 sec	
(*2*)	Short Stop I	3 min	68 F ± 1/2 degree
(*3*)	Hardener I	3 min	68 F ± 1/2 degree
	Wash and 2nd Expose	3 min	
(*4*)	Color Develop	15 min	68 F ± 1/2 degree
	Short Rinse	20 sec	
(*5*)	Short Stop II	3 min	68 F ± 1/2 degree
(*6*)	Hardener II	3 min	68 F ± 1/2 degree
	Wash	3 min	
(*7*)	Bleach	6 min	68 F ± 1/2 degree
	Wash	3 min	68 F ± 1/2 degree
(*8*)	Fix	6 min	68 F ± 1/2 degree
	Wash	3 min	
(*9*)	Final Wash	6 min	

As shown in Fig. 1, the lower layer of the emulsion records the reddish components of the image, the middle layer records the greenish radiations, and the top layer records the bluish colors in the image. In this way, a tricolor separation is made automatically and simultaneously in the selectively sensitized emulsion layers at the time of exposure. In this respect, Ansco Color Film is entirely conventional. The distinguishing feature of the film is the way in which the colors are produced. In each of the selectively sensitized emulsion layers a colorless dye former is incorporated at the time of manufacture. Each layer contains a different dye former which produces color complementary to the color sensitivity of the layer.

The top layer is sensitive to blue. After developing, the dye former in this layer will contribute yellow to the final picture. The middle layer is green sensitive and after developing, the dye former in this layer will contribute the magenta to the final image. The lowermost layer of the emulsion structure is sensitive to red and the

TABLE 2

Formulas for Processing Ansco Color Reversible Film

First Developer	pH 9.8–10
Metol	3 gm
Sod. Sulfite	50 gm
Hydroquinone	6 gm
Sod. Carbonate	40 gm
Pot. Bromide	2 gm
Sod. Thiocyanate	2 gm
Water to make	1 liter
Short Stop I and II	pH 5.3–6
Acetic Acid (glacial)	5 cc
Sod. Acetate	30 gm
Water to make	1 liter
Color Developer	pH 10–10.3
Sod. Bisulfite	1 gm
Colamine	4 gm
Sod. Carbonate	67 gm
Pot. Bromide	1 gm
Water to make	1 liter
Hardener I and II	pH 3.8–4.5
Pot. Chrome Alum	30 gm
Water to make	1 liter
Bleach	pH 6.2
Pot. Ferricyanide	100 gm
Pot. Bromide	10 gm
Dibasic Sod. Phosphate	40 gm
Sod. Bisulphate	35 gm
Water to make	1 liter
Fixer	pH 7.3–8
Hypo	200 gm
Water to make	1 liter

dye former in this layer will contribute the cyan to the final image. The dye formers used in the layers, each producing a different subtractive color, have the common characteristic that they will each combine with the same color-forming developer and remain in their respective layers without diffusing. This simplifies the developing process and makes it possible to use one color development to produce

3 different colors simultaneously, rather than an individual color development for each layer.

The developing process for Ansco Color Reversal Film, given in Table 1, consists of 9 essential steps with washes and rinses interposed where necessary. After camera exposure, the film is given a negative development in a metol-hydroquinone developer, Table 2. This develops the negative tricolor separation images recorded in the emulsion layers. At this point, however, no color is formed because color can only be formed when the film is developed in the proper color-forming developer. After developing, the film is given a short rinse and is short-stopped in an acid short-stop bath to arrest any further development. From the acid short-stop bath, the film goes directly into a chrome alum hardening bath. After hardening, the film is transferred to white light for the remainder of the process.

A wash follows the hardener and during this wash, the film is exposed again. Second exposure is accomplished by exposing both the back and the front of the film to GE *PS-25* Photoflood-type lamps. The color temperature of the light is not important. It is important, however, to have enough light intensity to expose completely all the remaining silver halides in the 3 emulsion layers.

During the second exposure, all silver halides in the film, which were not previously exposed in the camera and which did not develop in the negative developer, now become exposed and are ready for development in the color-forming developer. These silver halides make up the positive image. In the color-forming developer, this image is reduced to metallic silver by the action of the developer. Simultaneously with this reduction, reaction products—which always occur in developing—are produced. In a normal black-and-white film, these reaction products diffuse through the gelatin and are finally washed out in the developer and subsequent baths. However, in color film these reaction products combine with the color formers in the film and produce dye in proportion to the amount of silver halides which were reduced. Thus, as the 3 positive images in the film develop to metallic silver, 3 separate dye images are formed *in situ* with the silver images. Concurrently, therefore, a yellow image is produced in the top layer, a magenta image is produced in the middle layer, and a cyan image is formed in the lower layer. No color is formed around the negative image because this image is already in the reduced or metallic silver state and, consequently, no further reduction can take place.

After color developing, all silver halides in all the layers have been developed and dye has been formed around the positive image in each layer. Because of the silver present in the layers, it is not possible at this point to see any color in the film. After color developing, the film is rinsed and travels into the second acid short-stop bath. This bath arrests any further action of the developer and also tends to solubilize the residual color developer remaining in the film so that it can be more easily removed in subsequent steps. After the second short-stop bath, the film is given a second hardening treatment in the chrome alum hardening bath. This tends to maintain the hardness of the emulsion layer, making it resistant to subsequent handling. A wash follows the hardening bath.

As mentioned previously, the film now contains developed silver in all layers. In order to reveal the colors, this developed silver must be removed. The film is, therefore, treated in a bleach bath consisting mainly of potassium ferricyanide and a halogen salt which converts the developed silver back to silver halides. Since these silver halides are soluble in hypo, the film, after a brief wash, is fixed in a fixing bath consisting only of hypo. In this bath the rehalogenated silver is dissolved, leaving only the composite color images in the film. After washing, the film is dried in the conventional way.

Ansco Color motion picture film can be handled with equipment similar to that used for black-and-white film. However, the most satisfactory way to develop the film is with a developing machine. Hand methods of developing can be used, but such procedures cannot be considered production methods and the results obtained with them do not compare favorably with the results obtained with machine processing. We investigated many procedures for developing Ansco Color Film and we were called upon to devise procedures which could be used for field operation by our Armed Forces. During these investigations, we were not able to find any simple method which would produce ideal results. For field operation, however, the Stineman system worked out fairly well and the films processed this way, although not first-class from the technical viewpoint, were satisfactory and provided results where it would have been impossible to obtain them by any other procedure.

All types of Ansco Color Reversible Films are developed by essentially the same process. However, in mechanizing any process, a compromise has to be made between that which it is desirable to do chemically and that which it is possible to accomplish mechanically and still be consistent with good engineering practice. Developing machines of the production type ordinarily are built of a number of individual units, each unit carrying a number of film spools. In designing a developing machine to apply a process having numerous steps, it is customary practice to take the minimum time of film treatment in any one step and let this time be the governing factor in controlling the individual unit size of the machine. For instance, in the Ansco Color process having steps requiring several different treatment times, such as 12 min, 3 min, and 15 min, respectively, the individual unit size is so proportioned that a film treatment time of 3 min is given by one unit. The longer times are accomplished by increasing the number of units per bath to provide the increased time.

Our Ansco Color Film developing machines were designed and built during the war and in designing these machines a number of rather critical production requirements had to be met. The machines had to be designed to provide a rather large capacity in order to turn out the footage required. Slow-moving developing machines, ordinarily used in multistep processes of this kind, could not be considered. Furthermore, during the time of critical labor shortage, every labor hour had to be used conservatively. It has been our experience that it does not require more labor to operate a developing machine with fairly high capacity than it does to operate a small one.

The machine had to handle double-perforated (silent) film, sound film, and unperforated film. It could not place any undue strain on the film which might present a breakage hazard. Most of the films to be handled on these machines were important originals and could not be retaken in case of damage. Furthermore, it was a requirement that the machines be able to handle damaged film. Some of the films exposed in field operation are exposed under very unfavorable conditions which might result in damaged film. In such cases, all possible footage must be salvaged.

In order to meet these requirements, a sprocketless type of machine was decided upon and because of our experience with bottom-drive developing machines, a bottom-drive mechanism was used. Rollers which carry the film by the extreme edges were used throughout the machine in order to eliminate the possibility of friction marks on the sound track area. Hard-rubber rollers were found to be entirely satisfactory. The usual commercial hard-rubber film rollers, however, caused friction marks on the back of the film and, therefore, especially designed rollers were used. These were procured unbored. It has been our experience that rollers with the center openings molded are likely to be eccentric. This eccentricity can place undue strains on the film as the rollers revolve and for this reason, it was found preferable to drill the shaft openings in the unbored blanks with precision equipment.

The developing machines, shown schematically in Fig. 2, which we have designed for processing Ansco Color Film, have 25 units in the wet section and 4 units in the drying section, making a total of 29

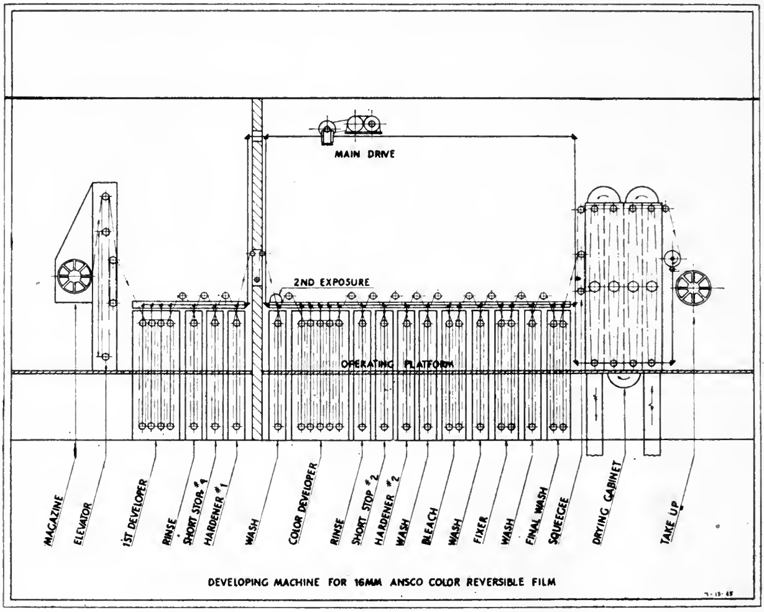


FIG. 2.

units which require more than 5000 ft of film for threading. Each machine is constructed in 2 parts—one part consisting of 7 units is installed in the darkroom; the other 18 units of the wet section are installed in white light. The roller banks are about $3^1/_2$ ft between centers and they are installed 8 in. apart on the top support. These are medium-speed production machines and have a variable operating range between 40 and 72 ft per min. They are normally operated at 60 ft per min. The film is driven by friction applied through the bottom drive. There are no sprockets. The machine is entirely self-compensating for dimensional change in the film.

The behavior of acetate safety film during the developing cycle is rather interesting. There are 2 factors which influence the dimensional change. One we term the "Humidity Coefficient" and this refers to the change of dimension which occurs when the film is subjected to moist air or water. The other factor we term the "Temperature Factor." This refers to the change of dimension in the film which occurs when it is subjected to changes of temperature either in air or in aqueous solutions. In processing, the dimensional changes occur continually as the film passes through the developing machine. These changes of dimension, seen in Fig. 3, are ordinarily not noticeable to the eye, but they are appreciable. Very careful

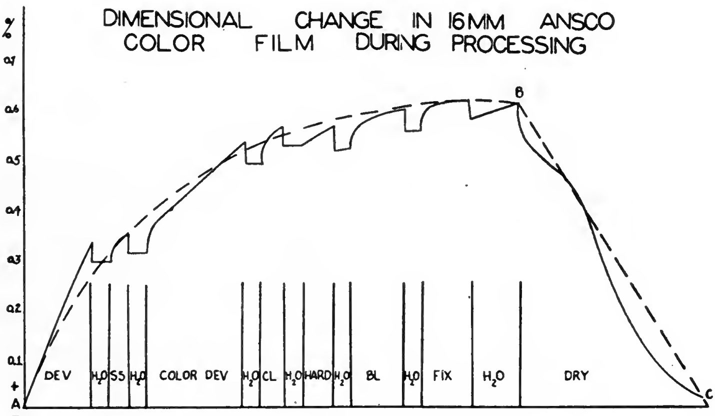


FIG. 3

consideration must be given to them when designing a developing machine; otherwise, the film will run with excessive tension in some sections and be excessively loose in others.

In order to compensate for these factors, all top rollers of the developing machine are free to move independently of each other. To insure this, a stationary separator washer is placed between each roller. This permits entirely independent movement of each roller without a tendency drag from neighboring rollers. This design will permit equalization in the wet section as long as the film is expanding, for it permits each loop of film free movement and slippage. It will not, however, compensate for shrinkage which must occur in the drying operation. In other words, it will take care of the dimensional change in the film, as indicated from point *A* to point *B* in Fig. 3.

From point B to point C a reverse condition exists and the film becomes shorter. In order to compensate for this reversed dimensional change, the drying cabinet is underdriven, which means that more film is drawn into the cabinet than is taken from it. This difference in drive is in relation to the dimensional change which occurs in the film.

By designing each section of the machine to compensate independently for these dimensional change factors, the tension on any part of the film at any point in the machine never exceeds 30 grams or one ounce. With this low strain on the film, breaks in the machine are extremely rare. We have some machines in continuous operation for more than 6 months at a time without a film break.

All metallic parts of the developing machines coming in contact with the solutions are made of 18-8 stainless steel. The solution tanks are made of steel, rubber coated $^1/_8$ in. inside and $^1/_{16}$ in. on the outside. It has been found that coating the tanks with rubber on the outside reduces the maintenance cost.

In operation, the film is fed into an elevator. The elevator holds about 120 ft of film. From the elevator the film passes over a break signal device into the first developing tank. There are 4 roller banks in the first developer giving a total time of 12 min at normal operating speed. After developing, the film passes successively into the rinse, the short-stop, the hardener, then through the light lock into white light. At this point it is given a second exposure. The second exposure is supplied by 4 GE *PS-25* lamps, 2 placed on each side of the film.

Simultaneously with the second exposure the film is given a 3-min wash and then goes into the color developer. There are 5 banks of rollers in the color developer. This gives a total time of 15 min at normal operating speed.

The next 4 units of the developing machine are in single tanks to accommodate the steps of rinsing, short-stopping, hardening, and washing. After the film has passed through the hardener and its subsequent wash, it travels into the bleach. The bleach tank accommodates 2 units and provides 6 min at normal operating speed. Bleaching is usually completed in $2^1/_2$ min. The extra time is provided to insure thorough bleaching. After bleaching, the film passes through a wash tank and then into the fixer.

The fixer tank contains 2 units allowing 6 min at normal operating speed. This insures complete removal of the rehalogenated silver.

The developing machine is provided with 2 wash tanks following the fixer. The first tank contains a single bank of rollers and allows 3 min of washing. This removes most of the fixer. The second wash tank contains 2 banks and provides the final wash of 6 min. The residual hypo left in the film after processing falls below 0.005 mg per sq in. which is satisfactorily low to insure permanency. After washing, the film passes through a double pneumatic squeegee, operating at 7 lb pressure, into the drying cabinet.

There are 4 banks of rollers in the drying cabinet and drying is accomplished in about 15 min. Clean, dry air is supplied to the cabinet from a dehydrator. The drying system is entirely closed and it is automatic in operation. The temperature is maintained at 86 F and the Relative Humidity is held at 35 per cent. In this system, if faster or slower drying is desired, the Relative Humidity is adjusted at the dehydrator. The air temperature is not changed. We have found this method of drying to be very satisfactory from all angles and it can be highly recommended.

The chemical mixing equipment is located on the floor above the laboratory and the solutions are fed through rubber pipe lines to the processing tanks of the machine. All make-up solutions are maintained at approximately the working temperature. This is accomplished by heat transfer coils located in all storage tanks. The temperatures of the processing solutions are controlled within narrow limits.

In order to insure sharp, brilliant color images, the developers, bleach, and the hypo are filtered and jetted against the film as it passes through the tanks. In the developing tanks, these jets are so arranged that the solution is directed against the flow of the film. This high turbulence provides a uniform development free from streaks usually associated with high-speed machine work.

During operation, the solutions are continually replenished. The amount of replenisher is determined by constant *p*H control and by sensitometry. Sensitometric tests are put through the developing machine every 30 min. These strips are checked for speed, color, and fog. A pictorial check is also made and in this test, short pieces of film, representing 3 different exposures of a predetermined setup, are developed together at 30-min intervals. The pictorials consist of a color chart and a gray scale. One series is given normal exposure; one series is exposed one stop less (this represents underexposure); and another series of exposures represents one stop more than normal, which is overexposure. A constant check is made on the gray scale for tone and the color patches are checked for general color characteristics. From these tests, it is possible to control the characteristics of the various solutions so that the quality output from day to day is uniform.

In conclusion, it can be said that Ansco Color motion picture film should not be developed by hand processes. Only a developing machine will give consistently uniform quality. Machine processing is the most satisfactory method of handling the film. Good turbulence of the solutions is necessary to insure clear, brilliant, sharp color images. No attempt should be made to operate a continuous color film developing process without adequate control facilities, for to do so will only result in failure. The control procedures necessary with machine processing of Ansco Color Film are not difficult to use. However, to interpret the result, it is obvious that a thorough knowledge of each step of the process is required.

DISCUSSION

Mr. E. E. Griffith: Mr. Forrest, when a sensitometric strip comes off the machine, what means do you have for adjusting the relative proportion of the color in it?

Mr. Forrest: The relative proportion of the individual color is not adjusted during developing because the color proportion is determined during manufacture of the film itself, not during the developing operation.

The color balance is established in reference to developers of known and carefully controlled characteristics. Exhaustion of the developers will affect this color balance and it is the purpose of the sensitometric strips to detect this variance and thereby provide a guide for the amount of developer replenisher required.

Mr. Ralph Atkinson: I would like to ask you to go into a little more detail as to how you would measure these differences in color in the sensitometric strip.

Mr. Forrest: The color in the strip can be measured with a color densitometer. From the density readings obtained from this instrument, the characteristic curves of the individual layers can be plotted.

Mr. Atkinson: Is it possible to vary the contrast of the image at all during processing?

Mr. Forrest: Very little control over the image contrast is possible by development changes.

Mr. A. R. Davis: Is it necessary to use four 500-w lamps for the second exposure, and should this light be of any particular color temperature?

Mr. Forrest: Second exposure requires a considerable amount of light because at this stage of the process the film has been slowed down considerably from what it was originally at the time of camera exposure. It is not necessary to use four 500-w lamps for exposure. At the machine speed at which we operate and under our particular conditions, we have found four 500-w lamps to be satisfactory. At slower machine speeds, a lesser quantity of light could be used.

In answer to the second part of your question, it is not necessary that the light be of any particular color temperature. However, the light should be of a continuous spectral quality. The important thing in making the second exposure is to provide sufficient light so that all the silver halides remaining in the film are thoroughly exposed. There is no danger of overexposing the film at this point.

MR. CHARLES G. CLARKE: I have noticed that the published directions for developing Ansco Color Film are considerably different from the method you have discussed for 16-mm film. For example, the washes between the developers and the short-stop baths are not called for in the amateur method which has been published.

MR. FORREST: The method of developing Ansco Color Film to which you refer has been worked out in connection with a developing outfit intended primarily for field use under various working conditions, and some of these conditions are very unfavorable for developing because of high water temperature. Because of this, the washes were eliminated, with a subsequent decrease in the life of the short-stop baths after the developers. For a continuous process, such as in developing Ansco Color motion picture film, rinses after the developers to prevent contamination of the short-stop baths are necessary. Motion picture processing laboratories, however, are usually supplied with cool water. Therefore, this provides no hardship in carrying out the continuous procedure.

MR. S. P. SOLOW: How does the developing machine compensate for dimensional change of the film?

MR. FORREST: In the developing machine described, the film is driven entirely by friction. Predetermined overdrive in the first section of the machine compensates for shrinkage. Elongation of the film takes care of itself automatically through the film's disengaging contact with the drying rollers at the points where the elongation occurs. Each loop in the developing machine is independent of its neighboring loops. This is accomplished by using a stationary shaft for the top rollers and providing a washer, which is keyed to the stationary shaft, between each roller. This prevents the action of any one roller from influencing the neighboring rollers and allows each loop in the developing machine to adjust itself automatically. This is a very important feature of this type of developing machine design. In operation, the compensation for dimensional change in the film from bath to bath is entirely smooth and automatic. The film travels continuously and smoothly through the machine. There is no jerking nor is there any slack formed at any point. Furthermore, there is no excessive tension built up. As mentioned previously, there is less than one ounce pressure on the film at any point in the machine.

MR. H. W. MOYSE: From the illustrations it appears that there is only one jet in the developer tanks. Does this provide sufficient turbulation?

MR. FORREST: Each tank of developer is provided with a series of vertical and horizontal jets so positioned that the angle of jetting is against the direction of film travel. The developer is supplied to the jets under pressure and this creates sufficient turbulence.

MR. R. C. MARTIN, JR.: Are there any squeegees between the various tanks? Isn't there a diluting factor caused by the water entering the various developers?

MR. FORREST: Rubber squeegees are provided between each tank. Since compressed air squeegees atomize the chemicals in the air, they are not used in this application. The rubber squeegees are fairly effective in reducing solution transfer from tank to tank.

Mr. Solow: The developing machine under discussion is a 16-mm machine. Do you have any experience with a similar setup for 35-mm?

Mr. Forrest: No, we have not built a 35-mm developing machine of this type, although there is no reason why a 35-mm developing machine made in accordance with this design would not work equally as well as the 16-mm machine, provided appropriate changes were made to accommodate the wider film.

Mr. Lynwood Dunn: Why cannot the contrast of the film be changed to a considerable degree during developing?

Mr. Forrest: When the recommended developing time for the film is used, all 3 layers are developed to the extent that they are in correct balance. This is not true when other than recommended developing times are used. Shortening or prolonging the developing time will affect certain layers of the film differently with the result that the color balance is disturbed.

Mr. Dunn: Would it be possible to restore the color balance by filtering?

Mr. Forrest: If the individual layers were thrown out of balance with each other through independent change in the characteristic curves of each, then a filter would not restore the color balance.

Mr. DeSorm: Could you use fluorescent lamps in place of the "inkies" and get enough exposure?

Mr. Forrest: Because of constructional details of our machine, the space is too limited to provide for enough fluorescent light to accomplish the second exposure. We do not recommend fluorescent light for second exposure because of its low intensity. There is always the danger that the film will not receive enough exposure. If this should occur, the bright mercury lines which are present would have a tendency to throw the film out of balance.

Mr. DeSorm: Fluorescent lights have been used in black-and-white.

Mr. Forrest: For black-and-white work fluorescent light may be perfectly satisfactory because the scale is monotone and is not likely to be thrown out of balance by an unbalanced exposure.

Mr. Martin: How practical is it to divide up the process—in other words, after the first developer, dry the film and then finish the process on another developing machine? Would this procedure cause any loss in quality?

Mr. Forrest: This procedure can be used. It may cause a slight shift in tone of the final image. However, this tone shift could be adjusted by making appropriate changes in the rest of the process. If a procedure of this type is used, it is very important that the film receive a good wash to remove all residual chemicals before it is dried.

Mr. Solow: How many of the solutions are circulating in the machine?

Mr. Forrest: Four solutions are circulated. They are the first developer, color developer, bleach, and hypo. The short-stop baths and hardening baths are not circulated.

Mr. Solow: Do you require any chemical replenishment during the course of operations?

Mr. Forrest: Yes, the chemical solutions are all continuously replenished during operation.

PRACTICAL UTILIZATION OF MONOPACK FILM*

CHARLES G. CLARKE**

Summary.—*Practical use has been made by the author of the Eastman monopack 35-mm color film in photographing the Twentieth Century-Fox Film production "Thunderhead." In this full-length feature production every scene was made on monopack film including interior sequences, process shots, special effects, and all of the exterior scenes. These latter were made under all variations of light conditions, and an extremely wide range of background material.*

The paper presents some of the problems encountered, the production techniques used, and benefits obtained by using this method of making motion pictures in color.

Having recently had a feature production released which was made entirely on monopack film, I have been asked to prepare a paper upon some of the experiences encountered and the technique attempted. The production is Twentieth Century-Fox Film Corporation's *Thunderhead—Son of Flicka*, which is the first 100 per cent feature production to be made by this Technicolor single-film method. By its nature, the requirements of this production gave monopack film a thorough test, for a great variety of scenic locations were utilized and every conceivable lighting condition was encountered which offered a challenge to the color camera.

Needless to say, much is yet to be learned about monopack, and no one at the present stage of development can presume to make any statements with final authority. As the monopack process is semi-experimental and little information about it is available, my experiences may be of interest and value to those who contemplate using this method of color motion picture photography in the future.

From the processing standpoint, monopack is more complicated than the older methods. Briefly, from the original monopack, which is a positive color print, 3 black-and-white separation negatives are made. From each of these a printing matrix is made which is then saturated with the proper liquid dyes, then transferred and superimposed one upon the other upon clear gelatine-coated film. The result is a color print from the original. The Technicolor Motion

* Presented May 17, 1945, at the Technical Conference in Hollywood.

** Director of Photography, Twentieth Century-Fox Film Corporation, Beverly Hills, Calif.

Picture Corporation has done heroic work in perfecting the process, so simply stated above, and they are constantly improving it. In the course of making *Thunderhead* I have seen the color reproduction improve, the emulsion speed increase 25 per cent, and the test pilot scenes come back to us much nearer normal as to color ratio and density. All this despite the fact that Technicolor is processing film in greater quantity than ever before and has contributed much of its highly trained and experienced personnel to the war effort. With these handicaps, plus the lack of needed machinery, Technicolor is experimenting with the monopack method, and research and improvements are constantly nearing perfection.

With these constant improvements that are being made, the problems and working methods of which I speak today may not apply in the future, and indeed may have been outdated by the time this discussion is published.

Basically, the technique of photographing in color will always differ from that of black and white, whatever the method. Color pictures have a roundness and third-dimensional effect of themselves, which has been striven for in black and white by utilization of lighting methods and employment of certain contrast values. While I am not of the school which maintains that color pictures must be made with flat light, and that pictorial color effects are to be avoided, still, I might suggest to the new worker in monopack that it is wise to proceed with caution. The tendencies of monopack to intensify contrasts must always be borne in mind. For example, slightly diffused daylight reproduces as bright sunlight in monopack, and light blue skies become vivid blue. Cloud-filled skies are most ideal, for not only do the clouds in the scene add beauty, but those behind the camera are reflecting white light into the shadows of the scene being photographed and are hence reducing the contrast of direct sunlight. Where these conditions do not prevail, reflectors and booster lights are used to fill in shadows. Arc lights equipped with ultraviolet *Y1* absorbing filters are used on booster lights as well as those used for interior lighting. Bunting diffusers are useful to soften overhead sunlight.

Monopack, in common with other color films, has a tendency to overemphasize the blue portion of the spectrum. To overcome this, an ultraviolet absorbing, almost colorless gelatine filter is used when photographing all scenes, exterior or interior. The filter is known as Wratten No. *114-A*.

Those having experience in photographing with Eastman Kodachrome reversal film will find that experience valuable when exposing monopack. In many ways the film characteristics of the two are the same.

It may be of interest to know that the exposure stops on *Thunderhead* ranged from *f*/2.8 to *f*/16. The interior scenes were photographed at *f*/2.8. Exterior exposures varied from *f*/2.8 for the dark canyon and waterfall scenes, which were made under the weakest of lighting conditions, to an average of *f*/8 for the regular landscape scenes. Cloud scenes and under-cranking to speed action accounted for the smaller stops mentioned. The exterior night scenes were, of course, taken in the daytime, and for these scenes the film was one stop underexposed to increase density of shadows. In the printing of these scenes we requested that the prints favor a bluish cast for the cool effect and to simulate the generally accepted conception of moonlight.

I have been frequently questioned about the scene containing the moon. This scene was made by employing an old trick of cameramen —that of double-exposing the real moon over an undertimed scene previously made in the daytime. The scene in this case was taken with a 35-mm lens exposed at *f*/11 and the moon was photographed that night with a 4-in. focus lens at *f*/2.8 on the same film.

Many of the same trick devices that are helpful in obtaining scenes with black and white may be made with single-film color. For example, in a scene preceding the horse fight, a split-screen double exposure was made on the location where the wild horse is apparently pouncing upon Roddy MacDowell. In the racing sequence there are 2 rear projection scenes, the plate being also photographed with monopack. Because of the fine definition of the process plate, these "process" shots are not inferior in quality with the normal scenes and can scarcely be detected.

To me, an interesting problem occurred in the sunrise sequence. To convey time lapse and distance covered, as well as an opportunity for pictorial effect, we dissolved from the night waterfall scenes to a sunrise scene. The next series of scenes which followed had to go on with the story and be delineated in full light. The sunrise scenes are naturally yellow in hue, as should be, but the next cut into the "hidden canyon," by necessity, had to be photographed at noon. At midday normal sunlight is white and vastly different in color from that at sunrise. Correction was made in color printing for the canyon scenes and we photographed these in such manner that this correction could be done without distorting the color of other known values.

For the horse fight scenes which followed the hidden canyon scenes, we selected a setting which was dominated by orange-red rocks. This orange-red background permitted normal color ratio to be resumed in printing. Thus the color transition was from a very yellow sunrise effect into normal daylight within a few feet of film, with only 2 short scenes color-manipulated. I do not believe audiences are conscious of this time lapse and color transition, but in any event it was one that required planning by the color cameraman, and needed the cooperation of the director and producer so that the scenes could be executed in this manner. In addition, the psychological effect of a primitive horse fight against a setting of vivid red background is in evidence here.

In a picture like *Thunderhead* panoramas were often necessary with the action going from front light to direct back light, and vice versa. This always presents a problem for color films, for among other problems there is the one of the change of hue in the sky between these extremes. Under clear conditions the sky in front light is quite blue, while the same sky in back light is white. In a motion picture these extremes cut together in rapid succession present a variety of hues to the audience and appear inconsistent. In rapidly "panning" shots there is not much a cameraman can do, though in slower panning shots some control is had by using graduated neutral density sky filters which are moved into maximum absorbing position as the camera pans into the strong back light. The exposure variable is controlled by the dissolving camera shutter or by the lens diaphragm during the taking of the scene.

Back light has been considered taboo in color, and in monopack it is difficult because of the added contrast. I must confess here to having put the film to severe tests in many cases. The porcupine sequence was deliberately photographed in direct back light because we wished to convey in this series of scenes the idyllic impression that highlights and reflections on running water and waving grass can give. Of course, a white horse and a lot of reflectors helped.

It may be proper here to enumerate some of the disadvantages of monopack in its present state of development.

First, there is the disadvantage in obtaining rush prints within the length of time we have considered reasonable with regular Technicolor and black-and-white prints. Naturally, to those using a new and unfamiliar medium, a print of maximum quality is desirable as soon as possible in order that a visual check may be made on the work that is being done. In this way errors of exposure and lighting may be corrected and future like mistakes prevented. With any reversible film, exposure must be correct within very narrow limits, as exposure determines photographic quality and correct color rendition. It is a tribute to the progress made by Technicolor that the exposure latitude has been widened with monopack and a certain amount of over- or underexposure may be controlled and brought into line through the latitude of the release print process.

At present, we view our "rushes" from a black-and-white print made by the reversal method. From an economic standpoint this is a great saving of film, for 6 more films would be necessary—3 separation negatives and 3 matrices for each scene printed in color. After a little experience in judging these reversal prints, the cameraman can gain quite a good conception of what quality the final color print will be. The film editor is at a disadvantage when cutting a production from these prints, for better selection and matching could be done if he were cutting from a color print. Rather than the black-and-white print, it would be better for the production if a contact print could be made on monopack, or some type of integral tripack film for the working print. The added cost of this film would be largely offset by the elimination of the color "pilot" test scenes which are now furnished, but which would no longer be needed.

Secondly, the film processing at the present time seems to add contrast, hence there is some exaggeration of color. In exterior scenes where the spectator has no standard values for comparison, this intensification is not too objectionable, but in the rendition of skin textures in close-ups, the audience knows what values to expect and too great a deviation from these norms results in unacceptable color rendition. As interior scenes are mostly composed of close shots of people, these scenes require a soft lighting technique for the most satisfactory results.

The question might be asked, "Why use monopack while it is in its experimental stages when the Technicolor 3-strip method is producing such fine results?" My answer would be, because of the greater facility in using standard motion picture cameras as against the heavier and more cumbersome 3-strip cameras. This is a most desirable requirement when photographing scenes in rough and difficult locations. In this connection, it may be stated that many of the scenes in *Thunderhead* could not have been put on the screen had it not been for the portable cameras that were used. Not only is production time saved in placing cameras, but camera angles can be employed and a greater selection of photographic lenses may be utilized. This is particularly so with the shorter focal length lenses, commonly called wide-angle lenses. Modern pictures utilize the advantages of wide-angle lenses for their greater depth of focus and interesting perspective renditions. With monopack it is possible to employ all the advances of the black-and-white photographic technique plus the greatly enhanced value of a production in full color.

Technicolor's monopack method provides producers with a medium for making productions in color when 3-strip color cameras are not available.

Prints from monopack reveal a great improvement in definition. To me, this is extremely important, for many film patrons complain "that they like color pictures but they hurt their eyes." I feel that it is not the color that has troubled them but rather that their eyes become strained and fatigued from trying to sharpen the diffused color print shown on the screen. While monopack prints leave more to be desired in this respect, still, they are sharper and better defined than the other methods now being shown. Separation negatives obtained from the monopack original are all equally sharp.

In this connection, all the lack of definition cannot be laid at the feet of color films. There is an appalling lack of care to focus the films properly in the theater's projection. Black-and-white film requires one setting and the thicker color film another in order to properly focus it. With the projectionist constantly interchanging films, both suffer neglect. It is to be hoped that audiences can hold on until the day when all pictures will be in color.

While I have mentioned the bad as well as the good things about monopack, I feel on the whole that monopack has given a good account of itself. When one realizes the enormous sums of money and the years of research that have been put forth by scores of color firms attempting to produce a successful product, I feel that the comparatively new monopack is off to an excellent start.

It is hoped that the suggestions I have tried to make, together with the results that are obvious when viewing our monopack picture and others to come, will aid users of this color method to obtain the wholly satisfactory results that are inherent in it.

A MULTISECTION RERECORDING EQUALIZER*

WILLIAM L. THAYER**

Summary.—*This paper describes an assembly of 5 equalizers arranged so that they can be controlled by one hand, thereby leaving the other hand free for dialogue level adjustments. The equalizers are capable of lowering or raising the response in 5 different frequency bands without creating changes in reproduced level.*

It is well known that it is necessary to equalize the frequency characteristic of recording systems when recording dialogue for motion pictures. Low frequencies are usually reduced, the shape and amount of the low-frequency reduction depending upon the microphone response, the closeness of the microphone to the actor, the low-frequency reverberation of the set in which a scene is being recorded, the effort with which the dialogue is read, the amount of bass in the voices, the loudness at which the dialogue will be reproduced in theaters, the frequency characteristics and reverberation characteristics in theaters, and other reasons. Also, to obtain best results it is often necessary to raise the high frequencies, or the mid-high frequencies because of theater high-frequency characteristics, microphone characteristics, or because of the position of microphones relative to the persons speaking.

A fixed equalization characteristic can be used for correcting fixed characteristics, but variable equalization is needed to correct unavoidable variations which occur from microphone positions, voice effort, voice characteristics, and set acoustics. In the past, efforts have been made to take care of all of the variations as they occur, during the original recording, but the tendency now is to apply a fixed amount of correction when making the original dialogue recording, and to vary the equalization during rerecording. One reason for this change is that the horn system, used in rerecording, offers a better facility for judging frequency response than the headphones used in making the original recording.

---

* Presented May 15, 1945, at the Technical Conference in Hollywood.

** Sound Dept., Paramount Pictures, Inc., Hollywood.

During the last few years a great deal of care has been taken in making the corrections during rerecording. Multistage equalizers have been built for correcting the low frequencies, the mid-high frequencies, and the high frequencies. Recently Paramount has been using additional equalizers for controlling the shape of the low-frequency equalization, and for raising or lowering the range between 300 cycles and 800 cycles. The number of controls for operating the equalizers has increased to five, and it has become a difficult problem

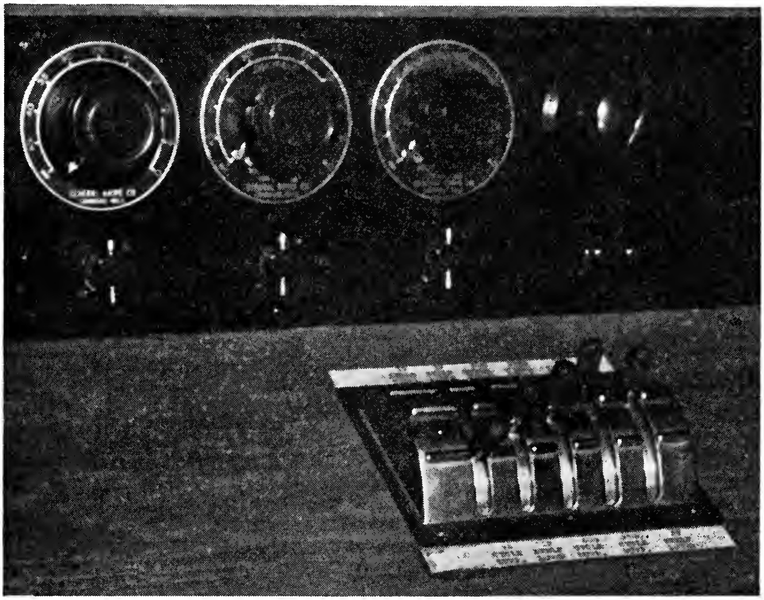


Fig. 1. Control levers.

to handle them properly, even though one man has been assigned the sole task of controlling the dialogue volume and equalization. Proper control of the dialogue level requires almost continual adjustment of a mixer dial, and consequently it is necessary to operate the 5 equalizer controls with one hand. To facilitate this, a 5-unit compensated equalizer assembly having lever controls has been built.

The assembly consists of 5 bridged-T constant resistance equalizers mounted in the mixing console, and electrically connected to control attenuators and compensating attenuators, which in turn are mechanically connected to a group of control levers through dial-tuning pulleys and cables. Figs. 1 and 2 show the control levers and attenuator assembly. Relays are operated by cam switches on the attenuator shafts, and are connected so that as the levers are moved through the center position, away from the operator, the equalizer elements are switched from connections which "lower" the frequency response to connections which "raise" the frequency response.

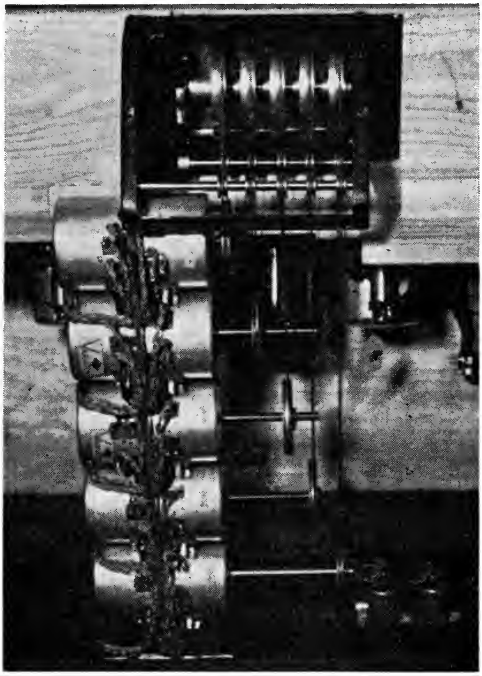


FIG. 2. Attenuator assembly.

Fig. 3 shows the complete electrical circuit, except that the relay circuit has been omitted for simplicity. To show the way the equalzer elements are switched, the first 3 equalizers have been shown with the "lower" connection, and the last 2 equalizers are shown with the "raise" connection. The 5 equalizers are connected in tandem, and are followed by the compensating attenuators and an amplifier having 35 db gain to give a zero loss system. The control attenuators have 8 steps for lowering the frequency response 1, 2, 3, 4, 6, 8, 11, or 15 db, and 7 steps for raising the frequency response from 1 to 7 db in steps of 1 db. The compensating attenuators have 7 db loss on the "off" position, and for all steps where the response is being lowered, and decrease in 1-db steps from 7 to 0 db when the control pots are raising the response from 0 to 7 db, respectively.

The equalization characteristics are shown in Fig. 4. The high-pass filter normally connected in the dialogue circuit is also shown. The full lines indicate the range in which each equalizer is normally used.

A wide variation in low-frequency shaping has been found to be desirable, and this is accomplished by using the relatively sharp 90-cycle equalizer in combination with the relatively flat nonresonant low-frequency equalizer. These equalizers are used mainly to obtain

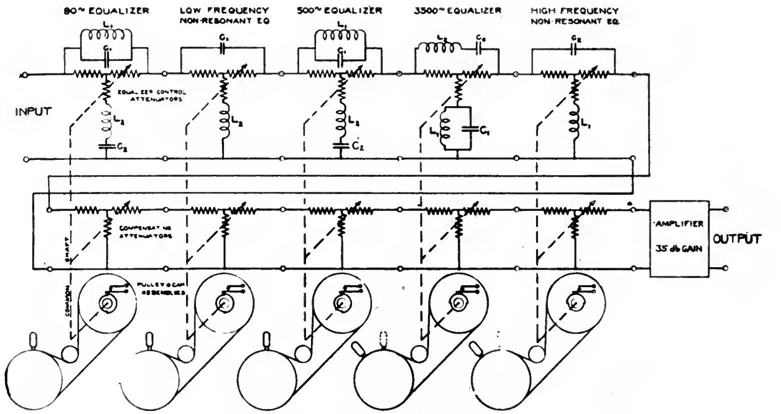


FIG. 3. Equalizer circuit.

a general reduction in "bassiness" and for correction of individual scenes. The original recording is normally recorded with a slight excess of bass to avoid getting "thin" recordings on raised voices. When it is necessary to add low frequencies it is usually done with the 90-cycle equalizer.

The 500-cycle equalizer is usually used for a general reduction in mid-low frequency "heaviness," or for giving body or fullness to scenes which are inclined to be thin. It is seldom necessary to use more than one or 2 steps of this equalizer.

The 3500-cycle equalizer is used extensively for treating "dull" scenes, and for improving intelligibility. It is very effective in restoring sufficient high frequencies for good intelligibility without causing an undesirable increase in film background noise.

The high-frequency nonresonant equalizer is too broad to use in large amounts, but is very effective in increasing "brightness" when used on steps +1 to +3.

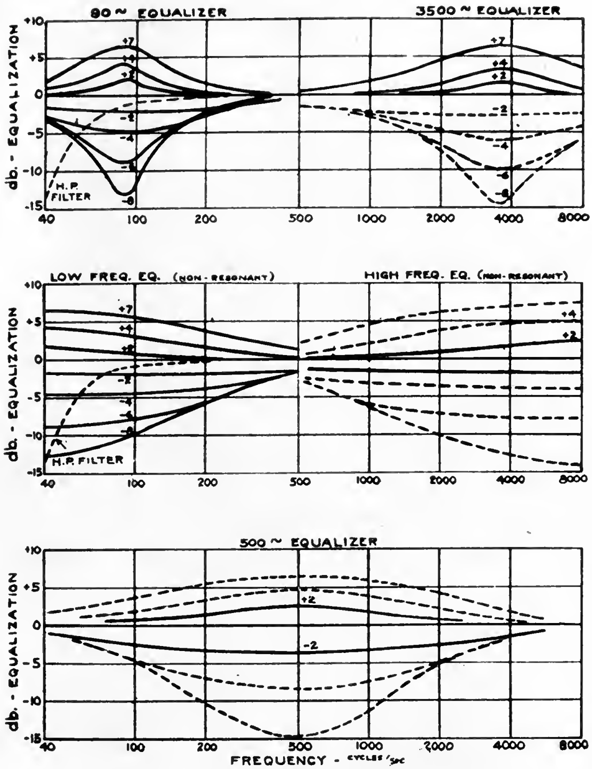


FIG. 4. Equalization characteristics.

In practice it is customary to set the controls to give the most desirable frequency response for the particular picture being rerecorded, and to deviate from these positions as required. Single dialogue lines which have been poorly recorded can be equalized so that fairly uniform intelligibility and frequency response are obtained throughout the picture.

REFERENCES

MILLER, W. C., AND KIMBALL, H. R.: "A Rerecording Console, Associated Circuits, and Constant *B* Equalizers," *J. Soc. Mot. Pict. Eng.*, **43**, 3 (Sept., 1944), p. 187.

ACADEMY OF MOTION PICTURE ARTS AND SCIENCES: "Motion Picture Sound Engineering," D. Van Nostrand & Co. (New York), 1938, p. 228.

ZOBEL, O. J.: "Distortion Correction in Electrical Circuits with Constant Resistance Recurrent Networks," *Bell. Syst. Tech. J.*, VII (July, 1928), p. 438.

FLETCHER, H. W.: "Speech and Hearing," D. Van Nostrand & Co. (New York).

AN IMPROVED LOUDSPEAKER SYSTEM FOR THEATERS*

J. B. LANSING AND J. K. HILLIARD**

Summary.—*This paper gives a description of a new 2-way loudspeaker for theaters. New permanent magnet low-frequency and high-frequency units having replaceable diaphragms are described. These units are combined in a horn system having the following advantages: A higher efficiency, extended frequency range, permanent magnet units providing higher air gap flux densities, elimination of backstage radiation from the diaphragms, better transient response, and an improved over-all presence.*

The use of the present 2-way multicellular horn systems over the period of the last 10 years has permitted the theater to give the public a sound quality representative of the sound recording technique available during the same period. However, during this 10-year period, experience has been gained indicating that still better recording technique is possible when better loudspeakers are available for monitoring purposes.

Accordingly, new loudspeakers are now being designed for this purpose, and it is the hope that they will bring the quality of sound even nearer to the ideal objective of sound engineers. We are sure that all of us will agree on this objective; we want improvement in both high- and low-frequency units, and we want the use of these units in a loudspeaker system having greater efficiency, higher power capacity per unit, better transient performance, an extension of the frequency range, a higher definition in quality, and a better over-all presence.

But it is necessary to have a new motion picture loudspeaker system (Fig. 1) in order to gain these improvements. Before such a new horn system could be developed, other things had to come. We had to have new methods of manufacturing diaphragms, we needed better voice coil construction, and magnets had to be developed that would be considerably superior to anything we have had in the past—and

* Presented May 14, 1945, at the Technical Conference in Hollywood.

** Altec Lansing Corporation, Hollywood.

these magnets came along as one of the developments in the war industry.

In the past, poor presence has been one of the principal deficiencies, which can be attributed to several causes. As an example, dips in the 250–500-cycle region tend to give the effect of individual low- and high-frequency sources. Resonances in the low-frequency units and horns have accentuated narrow bands. Backstage resonance,

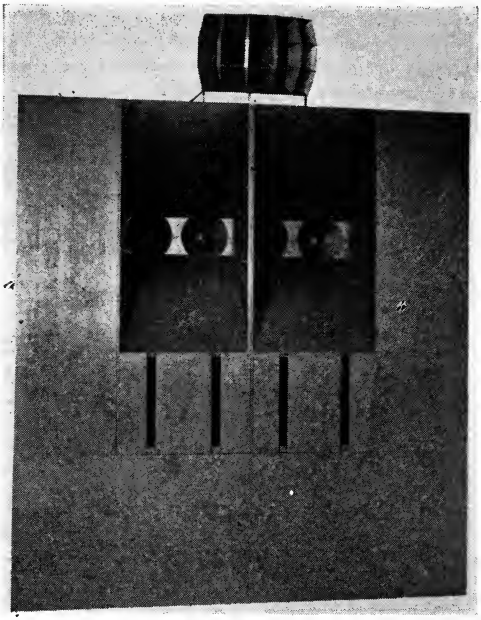


FIG. 1. Front view of *A-2* loudspeaker.

caused in part by radiation from the rear of the speaker system, has caused detrimental hangover and masking of the auditorium sound with an attendant loss of presence. Long air column low-frequency horns become involved in phasing trouble and loss of presence is encountered owing to the fact that the apparent source of sound tends to recede back in the horn progressively with an increase of frequency. Folding of the horn tends to limit the frequency range in proportion to the sharpness and number of the turns. Rigidity is necessary so that the walls of the horn will not vibrate and dissipate sound power by absorption and also give uncontrolled directional effects.

With this long list of difficulties in mind to begin with, new low- and high-frequency units were designed. These units have improved impedance characteristics, longer life diaphragms which dissipate more power safely, permanent magnet units with diaphragms that can be changed easily, and new magnetic circuits combining long life at high efficiencies.

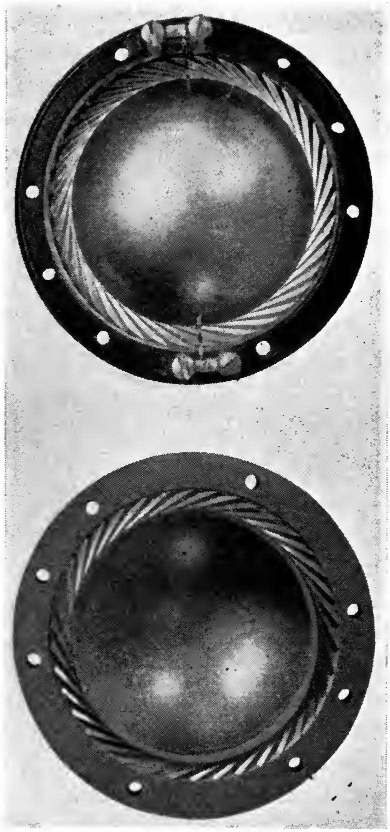


FIG. 2. Front and rear views of *288* replaceable diaphragm assembly.

288 HIGH-FREQUENCY UNIT

One of the basic improvements in the loudspeaker system has resulted from the design of a new high-frequency unit. The larger metallic diaphragm units available in the past have used the annular type of compliance. This type of compliance, while adequate at high frequencies, did not provide the necessary amplitude at lower frequencies. As a result, both the power and frequency characteristics in the region from 250–500 cycles have been found inadequate owing to the inability to handle the necessarily large excursion properly.

Back in 1925, E. C. Wente[1] of Western Electric recognized the necessity for a tangential compliance in loudspeaker units and microphones in order that the distortion be held to a minimum at low frequencies. Diaphragms used in the Western Electric *555* receiver had such a compliance.

Recently, J. B. Lansing has developed a hydraulic method of drawing metal diaphragms which simplifies the process considerably over the previous methods. As a result, it is now possible to draw larger diaphragms and provide a tangential compliance in these larger sizes. This method provides an amplitude approximately 3 times as great as the annular type and the increased length of compliance insures that the diaphragm (Fig. 2) can operate at the required amplitude without undue strain.

The voice coil is wound with rectangular aluminum ribbon which has been treated with a temperature resistant varnish so that it will safely dissipate higher power without damage. The use of edgewise wound ribbon provides more volume of conductor in the magnetic circuit which, in turn, increases the efficiency. Beryllium copper leads are spot-welded to the voice coil wires. This provides a heavy duty lead (Fig. 2) which will not fatigue under use.

FIG. 3. Side view of *288* high-frequency loudspeaker.

The entire voice coil and diaphragm assembly is mounted in a cast bakelite ring. The voice coil leads are clamped and soldered under flat terminals and a screw is provided for fastening each connecting lead to its binding post. By removing the leads to the binding post and 6 screws which anchor the bakelite ring to the top plate of the field assembly, the diaphragm and voice coil may be removed for replacement purposes. Two dowel pins are provided for alignment. The use of this method of mounting the diaphragm assembly permits its removal even though the magnet is charged. As a result, field replacement of the assembly is a simple operation and does not require that the entire unit be returned to the factory nor does it require any special tools.

The entire unit (Fig. 3) weighs 21 lb which is considerably lighter than previous units of comparable efficiency and power capacity.

The impedance of the unit when mounted in a properly matched horn is approximately 24 ohms over a wide frequency range.

Excitation of this new high-frequency unit is obtained from a newly developed Alnico No. *5* permanent magnet material. The flux density is greater than has been used in the best separately excited units supplied.

The magnet itself is of the center core type. The soft magnetic material forming the path between the pole pieces is amply designed so that the flux is conducted through the outside walls and up to the air gap with little loss. The external leakage loss is extremely low in

FIG. 4. View of *515* low-frequency loudspeaker.

this design and as a result does not attract metal objects in the immediate vicinity. The efficiency of the *288* high-frequency unit when mounted in a suitable multicellular horn is such that a sound level of 98 db (ref. 10^{-16} w per sq c) is produced at 5 ft distance for an electrical input of 0.1 w at 1000 cycles.

515 LOW-FREQUENCY UNIT

The *515* low-frequency unit is mounted in a 15-in. die-cast frame which assures permanent alignment of the cone and voice coil assembly as shown in Fig. 4. It uses a seamless moulded cone having an effective area of 123 sq in. and is moisture resistant. An edgewise wound copper ribbon coil (see Fig. 5) is attached to the cone and a dome is inserted in the center of the cone to provide the maximum active vibrating area. The use of edgewise wound copper ribbon improves the space factor over that of round wire and since more conductor material can be placed in the air gap, the efficiency is raised and the operating temperature decreased. Since the 3-in. voice coil diameter is considerably larger than the 2- and $2^1/_2$-in. diameter coils formerly used, it has a correspondingly increased ability to handle higher power without undue temperature rise, and, as a result, the efficiency is little affected with changes in power.

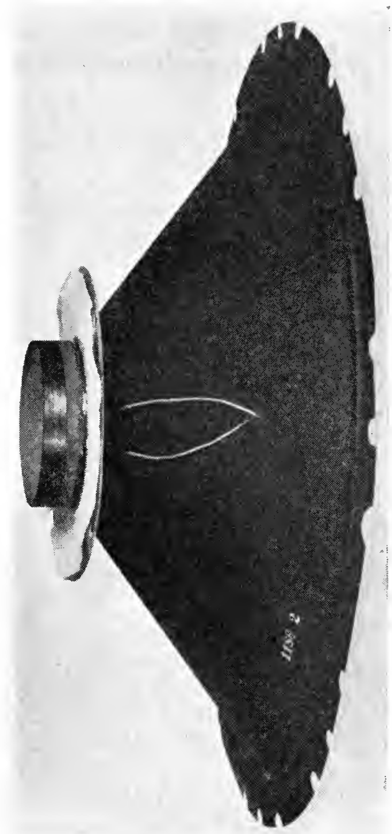


FIG. 5. Replacement cone and voice coil assembly for *515* low-frequency loudspeaker.

A clamping ring fastens the outer rim of the cone to the frame. The inner spider assembly is held down by means of screws so that it is a simple operation to remove the entire voice coil and cone assembly for replacement purposes.

An Alnico No. *5* permanent magnet is provided for the field excitation. The total energy available with this magnet is greater than that previously supplied in energized units now being used.

The resonance of the cone and voice coil assembly is 40 cycles in free air. The impedance of the unit is approximately 20 ohms as normally used. The unit will safely handle an input signal of 25 w. The unit is $15^3/_{16}$ in. outside diameter, 8 in. deep and weighs 33 lb.

DIVIDING NETWORK

The *N-500-C* dividing network used (see Fig. 6) is a parallel-type constant resistance network. It consists essentially of a low- and high-pass filter designed to operate from a common source at their input ends. The insertion loss of the network is less than $^1/_2$ db. The crossover point is at 500 cycles and at this point the power is divided between the high- and low-frequency legs such that each branch is down 3 db. The attenuation slope is approximately 12 db per octave on either side of the crossover frequency.

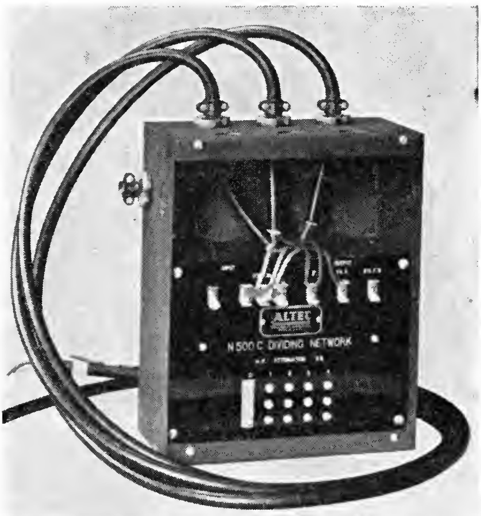


FIG. 6. *N-500-C* dividing network.

Provision is made for 5 steps (1 db each) of attenuation in the high-frequency output. This is accomplished by changing the shorting strip held under 3 screws.

The input impedance of the dividing network is 12 ohms.

COMPLETE SYSTEMS

The new improved low-frequency horn (see Fig. 7) which is used for medium size theaters has two *515* low-frequency units mounted beside each other in a straight exponential horn. The area of the throat of the horn has been made approximately equal to the area of the 2 diaphragms, giving a loading factor of unity. This increased loading over that formerly used provides better damping of the units and increases the excursion of the diaphragm.

These new units are enclosed from the rear (see Fig. 8) so that radiation from the back side is dissipated in the enclosure. However, at frequencies below 100 cycles this dissipation is not complete and ports are provided in the front of the speaker, below the mouth of the horn. These ports provide an acoustic impedance which raises the output

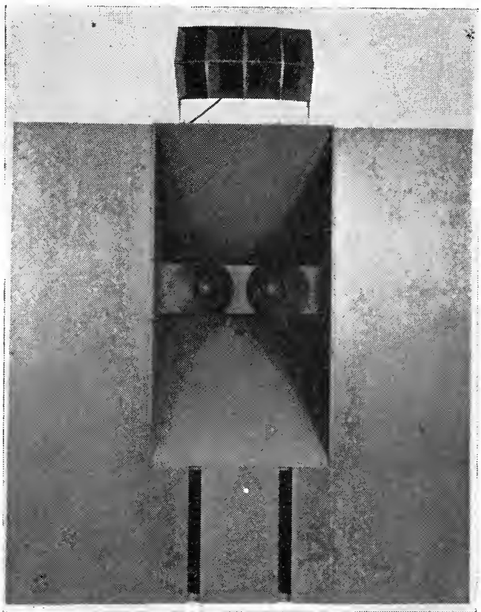


Fig. 7. Front view of *A-4* loudspeaker system.

several decibels around 50 cycles. Wings are provided for additional low-frequency loading.

One *288* high-frequency unit is used on the proper horn which depends upon the shape of the room.

Early experience with the first 2-way loudspeakers indicated that the relative phasing of the 2 units was important.[2] For correct phasing the 2 horns must have equal path lengths. The design of previous loudspeaker systems has not permitted this optimum phasing condition to be obtained. Measurements recently made out of doors in free space indicate that wide variations in response can be obtained at the crossover frequency when the horns are shifted so that the mouths of the horns are not in the same vertical plane. This new horn system has a path length such that the tip of the high-frequency multicellular horn mouth is exactly in line with the mouth of the new low-frequency horn for correct phasing, and under these conditions there is no variation in the response at the crossover.

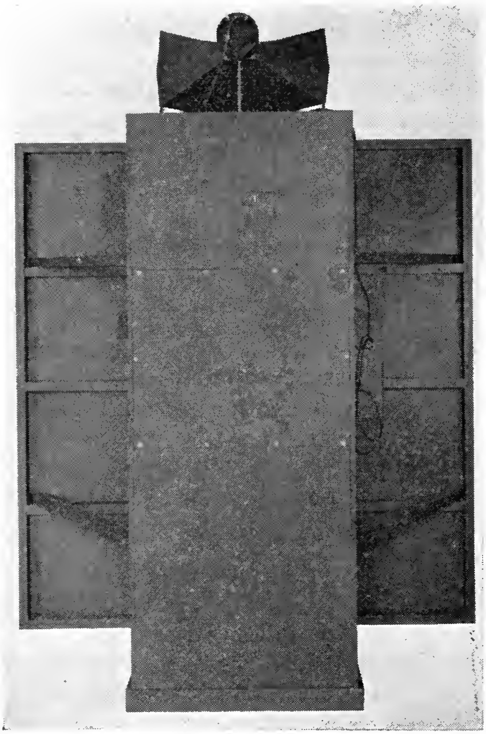


FIG. 8. Rear view of *A-4* loudspeaker system.

The *A-4* medium size horn system (see Fig. 7) has a rated capacity of 40 w. Destructive tests indicate that this rating provides a safety factor of greater than four over that necessary to damage the unit.

The *A-2* large size horn system (see Fig. 1) is composed of 2 low-frequency horns placed side by side and two *288* high-frequency units mounted on a double throat. The dividing network is mounted on the side of the baffle. The installation time is materially decreased, since the only wires needed are those from the output of the amplifier.

Sufficient damping of the vibrating elements of the units are provided in the magnetic circuit so that it is not necessary to provide additional damping from the driving amplifiers. In the past it has been customary to adjust the amplifier output impedance to a value of approximately one-half to one-third of the average loudspeaker impedance. Improved performance can be obtained with the new loudspeaker when the amplifier and loudspeaker impedances are approximately equal.

Anticipating that these new systems may be called upon to provide the sound channel in television work, it was necessary to restrict the stray magnetic field in order to prevent magnetic distortion of the television image caused by the proximity of the cathode-ray tube. Additional benefits from these features of the design are increased efficiencies owing to lower magnetic losses, and the fact that it is possible for these new permanent magnet units to be handled without endangering wrist watches or other devices which may be susceptible to damage from magnetization.

The efficiency of this new horn system is approximately the same as Dr. Fletcher's system[3] and is from 2–8 db higher than commercial loudspeaker systems now in use in theaters.

An *A-2* Altec Lansing horn system is now installed and is being used at the Pantages Theatre in Hollywood where field tests are being conducted. The Academy Research Council Standards Committee has recently had a meeting at the theater and has listened to the Academy test reel and current studio release product.

The electrical characteristic tentatively selected by this group is identical to the published metallic diaphragm characteristic[4] which has been adopted by the Committee for the range above 300 cycles.

Since the new horn systems have a smoother low-frequency response, experience to date indicates that a bass boost as much as 2 db at 50 cycles may be used with present product without interfering with dialogue quality. The straight low-frequency horn provides an unattenuated output up to and beyond the 500-cycle crossover point. This increased output in the region from 300–500 cycles over that of older horn systems adds materially to the presence and loudness of the over-all system. Recording and rerecording staffs in the studios indicate from their listening tests that over a period of time it should be possible to fully utilize the increased performance of the new loudspeaker system so that a smoother and more extended frequency and volume range can be reproduced.

It is our feeling that the early presentation of these loudspeaker systems will be a distinct aid to the sound equipment manufacturers in preparing their designs of future theater sound systems in order that the industry may not be limited to the quality standards established by older loudspeaker systems.

Similarly, the higher quality standards which can be reached through the use of these loudspeaker systems influence studio recording and monitoring practices. Because of the long interval which necessarily intervenes between the recording of a motion picture and its presentation to the public, considerable time must necessarily elapse before the full influence of the advancements in recording and reproducing can be presented to theater patrons.

The advantages of the new Altec Lansing loudspeaker systems are summarized as follows:

(*1*) Higher efficiency,
(*2*) Wider frequency range with a better transient response,
(*3*) New permanent magnets,
(*4*) Diaphragms that are easily replaceable,
(*5*) No backstage resonance,
(*6*) A higher safety factor at increased power,
(*7*) An improved over-all presence with a much better definition of sound quality.

REFERENCES

[1] WENTE, E. C., AND THURAS, A. L.: "A High Efficiency Receiver for Horn-Type Loudspeaker of Large Power Capacity," *Bell Syst. Tech. J.*, **VII**, 1 (Jan,, 1928), p. 140.

[2] ACADEMY OF MOTION PICTURE ARTS AND SCIENCES: "Motion Picture Sound Engineering," D. Van Nostrand & Co. (New York), 1938, p. 109.

[3] WENTE, E. C., AND THURAS, A. L.: "Loudspeakers and Microphones," *Bell Syst. Tech. J.*, **XIII**, 2 (Apr., 1934), p. 259.

[4] RESEARCH COUNCIL, ACADEMY OF MOTION PICTURE ARTS AND SCIENCES. "Revised Standard Electrical Characteristics for Two-Way Reproducing Systems in Theaters," *Tech. Bull.* (Oct. 10, 1938).

REVERBERATION CHAMBERS FOR RERECORDING*

M. RETTINGER**

Summary.—*The purpose of this paper is to discuss briefly the method of using so-called reverberation chambers for recording. After a general consideration of decay of sound in reverberant rooms, there is discussed the case where the reverberation of the chamber is superimposed upon that of the room in which the sound was originally recorded. Also discussed in the paper is a brief description dealing with the construction of a double reverberation chamber.*

In the recording of sound on film or wax it is frequently desirable to add a reverberatory quality to the recording after its completion. This may be accomplished by reproducing the sound in a highly reverberant room—the so-called reverberation chamber—and "mixing" the output from a microphone in this room with the original recording in a process known as "dubbing" or rerecording.

Surprisingly, when the electrical level of the reverberated signal is as much as 20 db below the electrical level of the original recording at the mixing panel, the combined reproduced signal conveys a strong impression of reverberation in every syllable of speech, and chord or passage of music.

Unlike in other means, electrical or mechanical, of adding a reverberatory note to a recording, the chamber method provides both the proper growth characteristic and the decay quality of sound in a live enclosure. Delay networks, magnetic tape recordings, and other devices for achieving synthetic reverberation usually permit only provision for the decay characteristic; no attempt is made to introduce the growth characteristic, since the latter is less essential in an approach to total reverberation.

It is interesting to plot the growth curves of sound and the corresponding decay characteristics for a number of rooms. Since we are dealing with enclosures having a little absorption, the following equations may be used to describe the build-up and the "die-away" process of sound in a confined space.

---

* Presented May 15, 1945, at the Technical Conference in Hollywood.

** RCA Victor Division, Radio Corporation of America, Hollywood.

Growth:

$$E = E_0\left(1 - \frac{1}{e^{\frac{14t}{T}}}\right)$$

or

$$10 \log_{10} \frac{E}{E_{00}} = 10 \log_{10} \left(1 - \frac{1}{e^{\frac{14t}{T}}}\right)$$

Decay:

$$E = \frac{E_0}{e^{\frac{14t}{T}}}$$

or

$$10 \log_{10} \frac{E}{E_0} = -\frac{60t}{T}$$

where E = energy-density at time, t
E_0 = steady state energy-density
T = reverberation period

Figs. 1 and 2 show the sound-growth and sound-decay curves for rooms that have different reverberation times, Fig. 1 being plotted on a percentage basis, while Fig. 2 employs the decibel as the unit for the ordinate. The curves are plotted on the assumption that the power output of the source in the different rooms is such as to provide the same value of steady-state energy-density in each enclosure. If the rooms were identical in shape, and the power output of the sources were the same, then the steady-state energy-density of the reflected sound only in the room with the 8-sec reverberation would be at least 8 times that in the room with the one-second reverberation. This may be calculated from the equation of the reflected sound energy-density.

$$E_R = E_0\left(1 - \frac{1}{e^{\frac{14t}{T}}}\right)$$

$$= \frac{4P\,(1 - a)}{caS}\left(1 - \frac{1}{e^{\frac{14t}{T}}}\right)$$

$$= \frac{4P\,(1 - a)}{caS} \text{ at } t = \infty$$

where P = power output of source
a = average absorptivity of wall material
S = total interior surface

For the addition of reverberation to recordings made on film, a room with a reverberation period of approximately 4 sec appears adequate. A chamber of 4000 cu ft volume, with walls and ceiling made

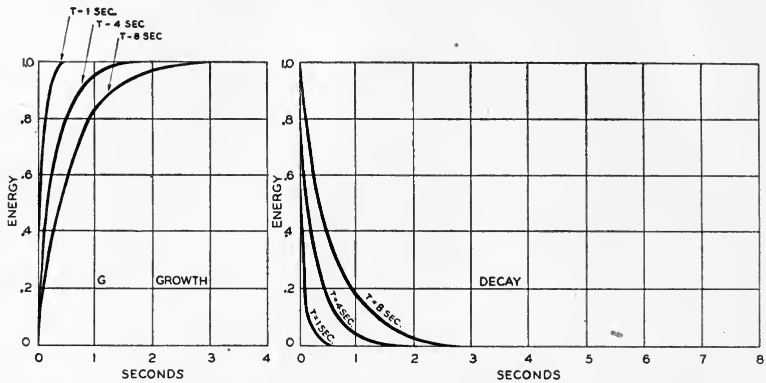


FIG. 1. Curves illustrating growth and decay of sound in different rooms, plotted on a percentage basis.

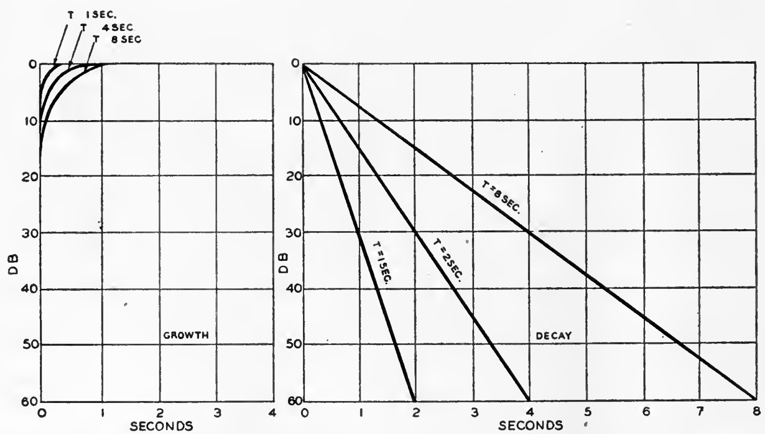


FIG. 2. Curves illustrating growth and decay of sound in different rooms, using the decibel for the unit of the ordinate.

of concrete, answers this purpose very well. If the mean dimensions for the height, width, and length of the enclosure are 12.5 ft, 16 ft, and 20 ft, respectively, the total interior surface comes to approximately 1540 sq ft. Crediting concrete, 6 in. thick, with an absorptivity of 0.03 sabine at 1000 cycles, the total absorption comes to 46.2

sabines, and the reverberation time therefore to 4.33 sec. Mean dimensions are indicated because the preferred shape of the enclosure is nonrectangular, in order to avoid flutter echoes.

It is interesting to consider the decay characteristic of the sound which actuates the microphone in the chamber. The sound which was originally recorded in the recording stage is itself characterized by the reverberation of the studio. During reproduction the decay characteristic of the chamber is superimposed upon that of the stage.

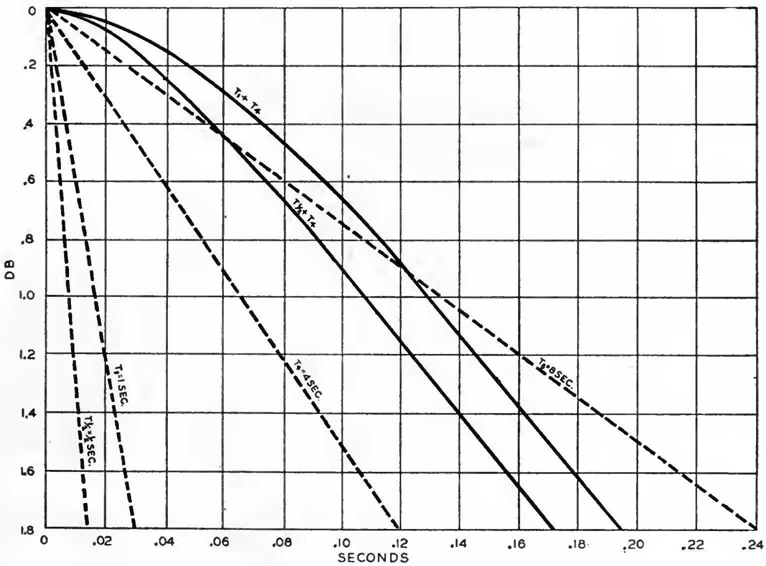


FIG. 3. Curves showing sound decay for combined reverberations.

The equation[1] for the combined reverberation times is given as follows:

$$E = E_0 \left(\frac{T_1 e^{-\frac{14t}{T_1}} - T_2 e^{-\frac{14t}{T_2}}}{T_1 - T_2} \right)$$

or

$$10 \log \frac{E}{E_0} = 10 \log \left(T_1 e^{\frac{-14t}{T_1}} - T_2 e^{\frac{-14t}{T_2}} \right) - 10 \log (T_1 - T_2)$$

In the case in which the reverberation time of the recording studio is one second and of the reverberation chamber is 4 sec, the equation reduces to

$$db = 10 \log (e^{-14t} - 4e^{-3.5t}) - 4.76$$

The curve is plotted in Fig. 3 together with one representing the combined reverberation of 0.5 sec for the recording studio and 4 sec for the reverberation chamber. Shown also in Fig. 3 are the theoretical decay characteristics of sound in rooms that have 0.5-sec, one-second, 4-sec, and 8-second reverberation. It is seen that for short

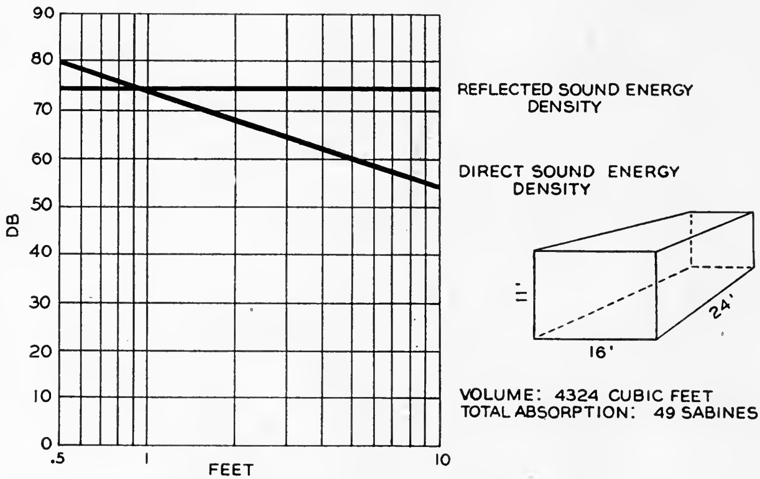


FIG. 4. Curves showing direct and reflected energy-density as a function of distance between source and pickup.

initial intervals of time the slope of the decay curve of the combined reverberation times is rather large. This may indicate that, to the ear, the combined reverberation time is in excess of anything that may be expected by an arithmetic addition of the individual reverberation periods. Thus, superimposing a reverberation period of 4 sec upon sound recorded in a room with a reverberation period of one second has, for short initial intervals, the effect of sound decaying in a room of 8 or more sec reverberation. This may account for the low electrical level of the reverberated signal necessary (at the mixing console) for its combination with the original recording to obtain the desired reverberatory character in the rerecording.

Another reason for the low electrical level required of the reverberated signal is the fact that the microphone represents only one ear. In binaural hearing, the ear is to some extent capable of suppressing unwanted sound, whether direct or reflected, and to concentrate only on the desired sound. This can be readily demonstrated by

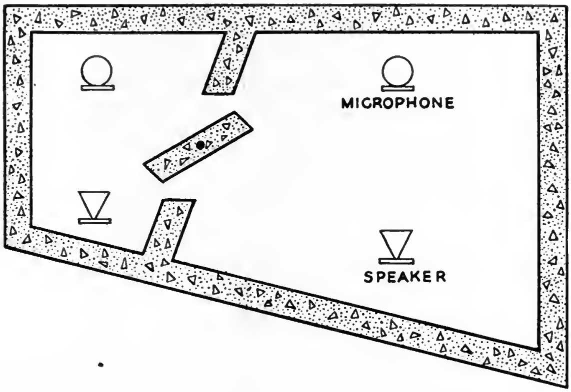


FIG. 5. Double reverberation chamber.

closing one ear in the reverberation chamber, in which case the reverberation appears considerably prolonged.

Another reason for maintaining a low electrical level for the reverberated signal is, of course, an attempt to preserve as much as possible the intelligibility of the dialogue. The ear is evidently able to

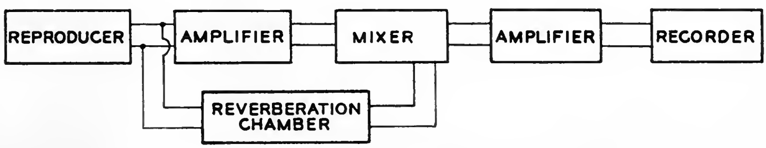


FIG. 6. Block diagram of rerecording channel using a reverberation chamber.

judge the reverberation of a room by the audible, slow trailing-off of the sound intensity at the end of *words*.

In the case of music, where longer reverberation tends to provide a richer or more pleasing quality, the electrical level of the reverberated signal is kept higher. Still, the definition of instruments can be preserved remarkably well by this means. One may indeed consider whether this type of reproduction does not supply a superior rendition, unattainable in any other way, since both clarity of instruments and an undertone of prolonged decay exist simultaneously.

Different recordings call for the addition of different amounts of reverberation, and sometimes, *for the addition of different types*, of reverberation characteristics. The reason for this is that, in sound-on-film recordings, a large number of different sound effects have to be included. If the dialogue is recorded in a cellar, tunnel, hull of a ship, *etc.*, but the incident sounds (footfalls, jack-hammer drives, engine noise) are not included in the original recordings, it is desirable to match the character of these effects with the "room-tone" existing in the surrounding in which the speech was recorded. Some variation in the reverberation characteristic can be effected by changing the

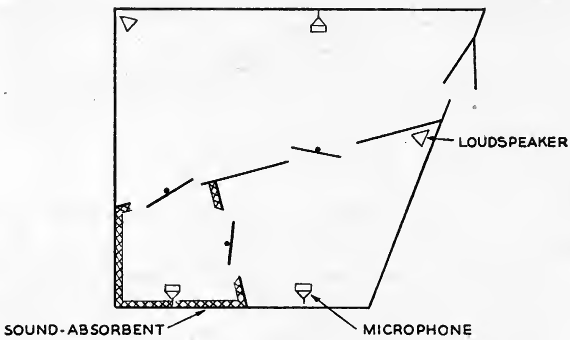


FIG. 7. Triple reverberation chamber.

distance between loudspeaker and microphone, since this will change the ratio of direct-to-reflected sound at the microphone. Fig. 4 shows the direct and the reflected energy density for the room indicated in the figure.

The character of the reverberated signal may be altered more perceptibly by dividing the chamber into a small and a large room. Since the number of normal modes and their spectral distribution is decidedly different in 2 such enclosures, a considerable variation in the quality of the signals may be effected by using one or the other of the 2 rooms. If a door is provided in the partition between the 2 chambers, a further variation will result by placing the speaker in one of the rooms and the microphone in the other. Such a door acts like an acoustic high-pass filter, thereby making the reverberation characteristic of each room a function of the door opening.

A change in the character of the sound picked up in the chamber can, of course, also be secured by using different microphones.

Fig. 5 represents the plan of a dual reverberation chamber, of which the walls as well as the ceiling and the floor were kept at a slant to avoid echoes. Two such dual chambers employed concrete for the material of the walls, the ceiling, and the floor. A massive door, 5 ft wide and 6 ft high, weighing approximately 450 lb, could be rotated by means of a knob located at the rerecording console; in this manner it was possible to change the reverberation characteristics of the rooms easily and quickly.

Fig. 6 shows a block schematic of a recording channel employing a reverberation chamber.

Fig. 7 illustrates a triple reverberation chamber, designed for the purpose of achieving extreme flexibility in rerecording work.

REFERENCE

[1] HILL, A. P.: "Combined Reverberation Time of Electrically-Coupled Rooms," *J. Acous. Soc. Amer.*, **4**, 1 (July, 1932), p. 63.

CONTINUOUS FLASH LIGHTING—AN IMPROVED HIGH-INTENSITY LIGHT SOURCE FOR HIGH-SPEED MOTION PICTURE PHOTOGRAPHY*

HENRY M. LESTER**

Summary.—*High-speed motion picture cameras capable of taking pictures on continuously moving film at the rate of upward of 3000 frames per sec produce individual exposures on the order of* $^1/_{15,000}$ *sec or less. Exposures of such brevity, however, call for continuous illumination of great intensity, and incandescent lamps, which are adequate, have many disadvantages. Among these are: excessive consumption of electric power, heavy conductors and connectors, emission of considerable heat, and appliances and reflectors of great bulk and weight.*

Since the actual time during which such high-intensity illumination is required seldom exceeds one second, certain flash lamps will provide satisfactory illumination when operated in suitably designed equipment. Flashing successively on the current of a 6-v dry-cell battery, one or more flash lamps will yield light of high actinic value and of easily controlled direction and duration.

Special equipment, known as the Continuous Flash Lighting Unit, accomplishes such purposes effectively, providing adequate illumination both for black-and-white and natural color high-speed motion pictures. This paper reviews the development of the Continuous Flash Lighting Unit, and describes its operation and advantages.

Customary Lighting.—The problem of illumination grows in truly geometric progression with the size of the area to be photographed. Each user of the high-speed camera solves this problem differently, depending upon the subject under investigation and local conditions.

A most universally successful solution in general is provided by the use of "over-volted" incandescent lamps, such as the Mazda *R-2* Reflectorfloods and the Wabash Reflector Superfloods. Both operate at high intensities on 115-v current. The GE 150-w projection spotlight lamp, although rated at 120 v, provides adequate illumination for high-speed photography when operated on 220-v.

Though relatively short-lived, these lamps provide satisfactory illumination for small objects which can withstand the intense heat

* Presented June 13, 1945, at a meeting of the Atlantic Coast Section of the Society in New York.

** Cinematographer, Editor, Photo-Lab-Index, New York.

emitted by the lamps when used at close range. These lights must be used at distances of 12 to 16 in. from the subject, with their light beams superimposed.

Four Mazda *R-2* Reflectorflood lamps placed about 16 in. from the subject, with their beams superimposed, will illuminate adequately an area approximately 9 in. sq for an exposure of 2500 frames per sec, with the lens set to *f*/2.7. The current consumed by these 4 lamps is 20 amp at 115 v. Voltage should not be allowed to drop much below that level, if the exposure is to be acceptable. The "bluishness" of the Photoflood lamps, measured by the high color temperature at which they operate when over-volted, drops off rapidly as the voltage is reduced. A drop of 5 v from the rated level will lose as much as 100 K, resulting in considerable loss of the actinic value of the lamps.

Obtaining 20 amp of 115-v current may not be much of a problem in most locations. Yet it can be a headache when 4 Reflectorflood lamps are inadequate for the illumination of some subjects or, for that matter, "too hot to handle" in connection with others. The heat emitted by these lamps can have undesirable or adverse effects upon some subjects to be photographed. Take the case of the center portion of a large aircraft propeller blade which had to be photographed in motion (vibrating): An area some 20 in. sq had to be illuminated to a higher than normal level because of certain requirements of the investigation. More than 20 kw of power, and a transformer, had to be used. Incidentally, 20 kw of electric power call for No. *OR* conductor cable. Photographically, the results were entirely acceptable. Yet the steel blade, housed in a relatively small compartment for this investigation, became so hot during the preliminary focusing, line-up, and several exposures that some doubt was cast upon the validity of certain observations made on viewing the footage. On that job the cameraman and his associates were nearly roasted in more ways than one.

The Origin of the Idea.—A recommended solution to this illumination problem originated in the mind of a cameraman whose assignments vary and whose problems, often hundreds of miles apart, have the added distinction of dissimilarity. It suggested itself during a high-speed investigation of the action of Photoflash lamps synchronized with camera shutters of various types. In this case there was no problem of rendering the subject visible. The subject itself was self-luminous.

The shutters required no illumination because another flash lamp, placed behind the shutter, served to illuminate the opening and closing of the shutter blades, or the movement of the curtain slit. However, owing to the high level of light intensity of these 2 "performing" flash lamps, *their* flashes seemed to appear upon the screen as coming from nowhere. They bleached all adjacent detail of auxiliary equipment, and gave the audience no opportunity to orient itself to the relationship of the various parts in the field, or to recognize the type, size, and character of the flash lamp shown, or the synchronizer, or the shutter.

It appeared desirable to "pre-illuminate" each performing flash lamp in such a manner that it would be seen together with its properly arranged accessory equipment for some time before its action started. Reflectorfloods were found to be too weak. Since many of them had to be used, their multiple reflections upon the glass envelope concealed too much of the inside of the flash lamp. Backlighting, which would have been effective for the illumination of a flash lamp alone, could not be used because cameras, shutters, and synchronizers adjoining the flash lamp in the picture had to be lighted too. Obviously, "the wedge had to be knocked out by means of another wedge." A single flash lamp in a reflector was placed several feet away from the subject and directed upon the scene. Fired slightly before the flash lamps being photographed flashed, it provided the necessary illumination, a desirable "fade-in," and a balanced exposure at $f/8$.

The preillumination Photoflash lamp was fired by a 6-v current closed by the camera's Microswitch, which was pre-set to a predetermined point of the footage. The same contact-maker also tripped a delayed action relay, which closed, a little later, the circuit of the synchronizer flashing the performing lamps and moving the camera shutter. The delay was about 10 milliseconds. Thus, the flash lamps and the camera setup, the combined action of which was being studied, were first illuminated by the light of a flash lamp, then put in action by the simple relay.

At the high operating speed at which these pictures were taken, the light emitted by the flash lamp exposed a considerable footage of film. At 3000 frames per sec the camera exposes 3 frames during each millisecond. Since this particular flash lamp has a flash duration of some 60 milliseconds, its light illuminated some $4^1/_2$ ft of film. In addition, it was noted that the light transition from the preillumination lamp to the performing lamps was quite smooth and not apparent to the audience. This suggested the possibility of using Photoflash lamps, fired in suitable succession, as a source of high-intensity illumination for high-speed motion picture photography.

Many Advantages.—This possibility appeared immediately as most attractive in many respects. Electric current requirements are reduced to nothing more than a 6-v dry-cell battery. The heat emitted by the flash lamps, being only momentary, is negligible. Further, the high blue-light content, or the high color temperature, of Photoflash lamps (3800 K) being substantially higher than that of Photoflood lamps (3400 K), and being entirely independent of line voltage fluctuation—since the light output is based upon the uniformity of the inflammable charge—promised a light of much higher actinic value.

Other advantages are found. These include smaller lens stops, greater depth of field, greater over-all sharpness. Also, it would appear that exposure calculations are simplified, heavy cables dispensed with, and the entire outfit made quite portable because most of its electric power requirements are self-contained.

The method, however, took some working out. To minimize unevenness and pulsation of illumination and to reduce to a minimum the number of flash lamps in a cycle, a lamp was needed which produced the longest flash. Such a lamp was found in the Mazda No. *31* Focal Plane Photoflash lamp, made by the General Electric Company and the Westinghouse Company. With peak reaching approximately $1^1/_2$ million lumens, flash duration at one-half peak is around 55 to 60 milliseconds (about $^1/_{20}$ sec). Since the combined brightness of 4 *R-2* Reflectorflood lamps adds up to only some 68,000 lumens, the advantage of the output of a suitable flash lamp cycle is obvious.

Another flash lamp suitable for the same purpose is the Wabash No. *2A* Superflash lamp. It has similar performance characteristics, but slightly different physical dimensions. This lamp cannot be substituted for the Mazda lamps, nor should it be mixed with them in the same cycle. Either the Superflash or the Photoflash lamps are suitable for this purpose.

The Prototype of the Equipment.—Considerable experimentation with the No. *31* Photoflash lamps, combined with extensive calculations and plotting of the time-light characteristics of the flash lamp (Fig. 1) led to the construction of a revolving contactor on an experimental basis. The unit consisted of a flat panel of aluminum upon which were mounted 15 lamp sockets, each wired to a rotating "distributor," shown in Fig. 2. A synchronous motor revolving at 75 rpm rotated a sliding contact, which made one revolution in $^4/_5$ sec (800 milliseconds). The sliding contact was made to rotate continuously and the battery current required for the firing circuit was closed at an appropriate moment by a holding relay, activated by the Microswitch on the camera footage indicator.

This prototype of the continuous flash lighting unit was used and experimented with quite extensively. Exposures made with it were found to have a reasonably satisfactory evenness of illumination.

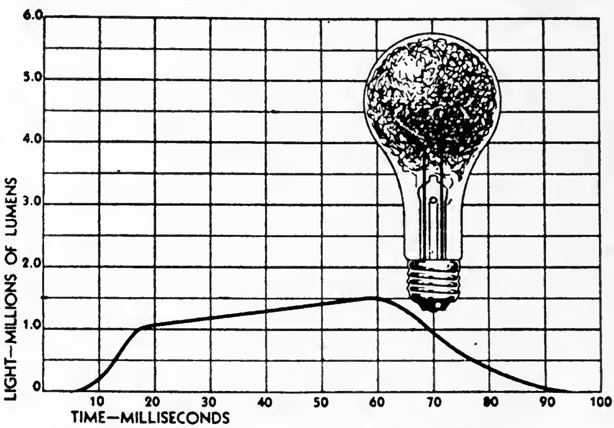


Fig. 1. Focal plane Mazda Photoflash lamp No. *31*.

Views were obtained of larger areas at smaller lens apertures, with the lights farther away from the subject than had been possible with incandescent light sources.

However, several drawbacks soon became apparent. The lamps were arranged upon the panel in 3 rows of 5 lamps each, spaced rather widely, though uniformly. The generous spacing was provided partly to gain some reflection of the light from the aluminum panel, partly because of the physical dimensions of the lamp sockets, but not to avoid flashing of the lamps spontaneously "by contact." Only the earlier foil-filled types of flash lamps fired "sympathetically," when in contact with other flashing lamps. The wire-filled, or the shredded foil-filled lamps, do not act in such a manner.

Although the lamps were wired in sequence to the distributor, since the contactor was turning continuously before the flashing cycle started, it was never possible to predict which lamp was going to fire first. The gap between the flashes of lamps from opposite corners of the rectangle, and the generally broad spacing between the lamps, produced a directional shift of the successive light sources. This was noticeable in the exposed footage, lights and shadows shifting across the subject. The flat reflector proved to be inadequate, for the light lacked necessary "punch" and direction.

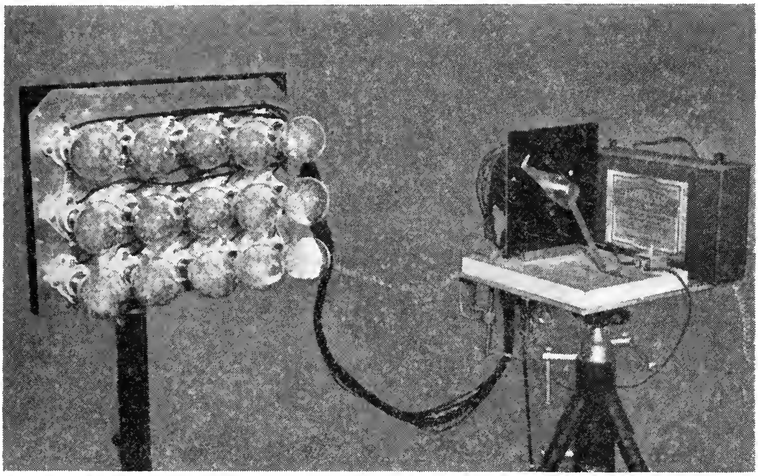


FIG. 2. Original experimental continuous flash lighting unit, employing 15 No. *31* Photoflash lamps.

Present Equipment.—Further experimentation with the flash lamps revealed that a much more satisfactory flashing cycle would result from the use of 17 flash lamps. These would yield a fairly level output of something over $1^1/_2$ million lumens for a full second, sufficient time to expose some 60 ft of film at 3000 frames per sec, and greater footage at higher speeds of camera operation.

In the present equipment, each of the 17 No. *31* Photoflash lamps is held by a special thin-walled slip socket, mounted upon the outer circumference of a wheel of some 8 in. in diameter. This forms the flashing rotor, which is driven by the slow shaft of a synchronous reducer motor and revolves at the rate of one revolution per second. Its rotation results in the firing of the lamps at intervals of $^1/_{17}$ sec (approximately 59 milliseconds).

Fig. 3 shows the time-light characteristics of 2 successively flashing lamps and the resulting composite curve representing their combined light output. The graph shows that there is a time lag of approximately 7 milliseconds after the flashing circuit is first closed and before the illumination starts. At 10 milliseconds the light level reaches about 250,000 lumens; at 14 milliseconds, 500,000 lumens; at 18 milliseconds, 1,000,000 lumens. Thereafter comes a slower rise to $1^1/_2$ million lumens and beyond at 59 milliseconds. At this point, however, contact is made for the next adjoining lamp, the light output of which starts at about 66 milliseconds—counting from zero time—just as the light of the first lamp begins to fall off. The cumulative effect is shown by the solid line, revealing a momentary

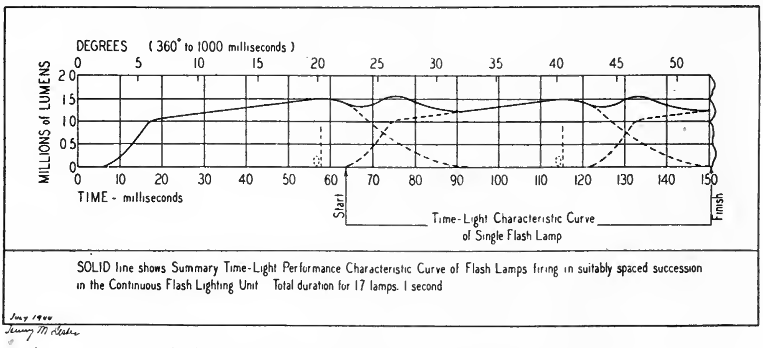


Fig. 3. Two of the 17 cycles of flashes which occur during one second of continuous flashing in the rotary unit.

dip in the total illumination, followed by a small rise, the composite of the rise and fall of the light output of the 2 respective adjoining lamps. At 90 milliseconds, the first lamp is completely out, and the light level curve is that of a single lamp again. At 110 milliseconds the firing contact is made for the third lamp, and the cycle is repeated.

Obviously, an absolutely even, straight-line level of illumination is not attained. However, the variation appears to be within the limits of 1.25 to 1.60 million lumens, a difference well within the limits of latitude of black-and-white film. Actual experience bears out that although discernible, the light fluctuation is not at all objectionable when the film is viewed. In color films this fluctuation is slightly more pronounced, but still quite acceptable.

The flashing rotor, carrying the flash lamp sockets, contains within its underside a large segment commutator serving as the distributor for the firing current. Each lamp socket is connected to its corresponding bar on the commutator, and contact is made by a brush extending from the frame of the motor unit. The order of firing and the exact interval between the contacts is thus predetermined and fixed by the construction of the commutator. The commutator and the contact brush are adjustable with respect to the lamp sockets, so that the exact position of the firing point for all 17 lamps can be adjusted through an angle of some 15 degrees. This adjustment is useful not only for the consummation of the entire flash within the physical

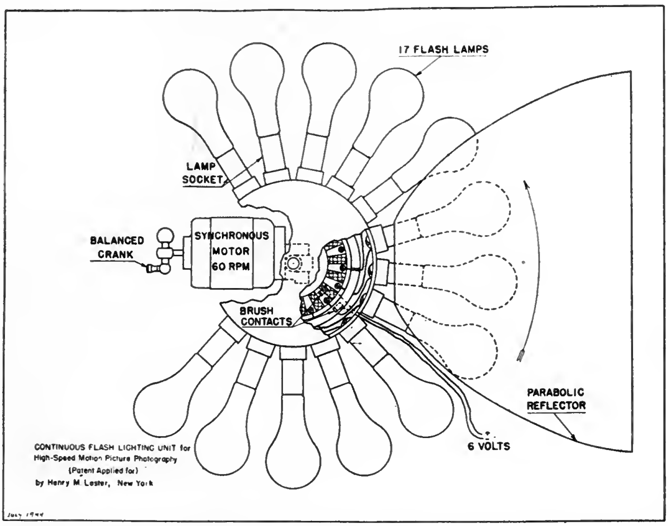


FIG. 4. Top view of continuous flash lighting unit showing relative position of lamps on rotor.

confines of the reflector, but also, when 2 such units are used simultaneously, to level off the resultant light output of both light sources. It is possible to set the flashing rotors with respect to each other in such a manner that the peaks of one cycle occur during the valleys of the other, and vice versa.

The relation between the flashing lamps and the reflector is shown in detail in Figs. 4 and 5. As drawings and photographs indicate, the reflector is provided with a cutout gate through which the revolving lamps enter and leave the reflector. Ideally, the lamp should make contact just as it enters the confines of the reflector, and reach its maximum peak of light as it crosses the focal point of the parabolic reflector. This adjustment is easily obtained and, once set, is permanently maintained by means of setscrews.

The motor is started substantially before the camera. The flashing rotor will revolve before and after the flashing cycle until shut off.

The reflector is made of a special aluminum sheet, Alzak finished, its surface directing upon the subject 5 to 7 times the bare lamp value of light.

The Control and Power Unit.—Figs. 6 and 7 show the power and control unit, which contains an ordinary 6-v dry-cell (Hot Shot)

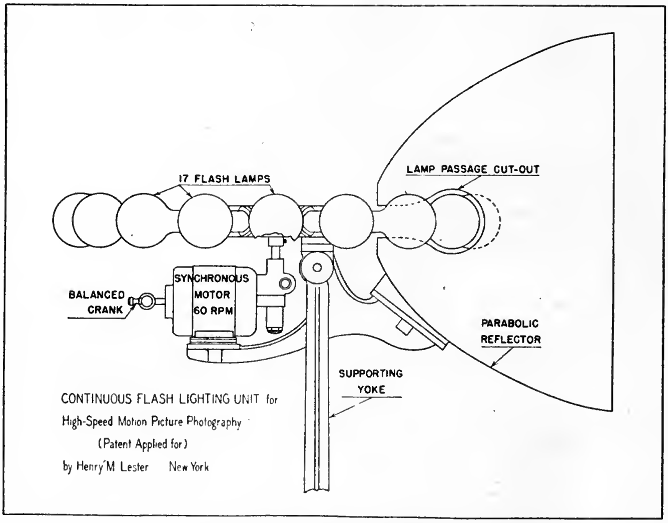


FIG. 5. Side view of continuous flash lighting unit showing adjustable support of motor, rotor, and reflector on *Y* yoke.

battery. This provides an almost inexhaustible source of electric current for the flashing of the lamps. The unit has 2 polarized receptacles for 4-conductor Jones connector plugs connecting one or two of the continuous flash lighting units through a shielded cable. The 4-conductor cable carries the alternating 60-cycle, 115-v current to the synchronous reducer motor driving the flashing rotor, and the 6-v current distributed to the flash lamps through the commutator. The control unit contains, also, the locking relay, which maintains the battery current through the commutator until all the 17 lamps have been fired after the contact has been made by the Microswitch on the camera. The control unit permits the operation of one or 2 of the units on a remote control basis.

Even Illumination.—Obviously the evenness of illumination depends upon all lamps firing uniformly and correctly. Excessive resistance in flash lamp circuits results in their delayed firing if, in-

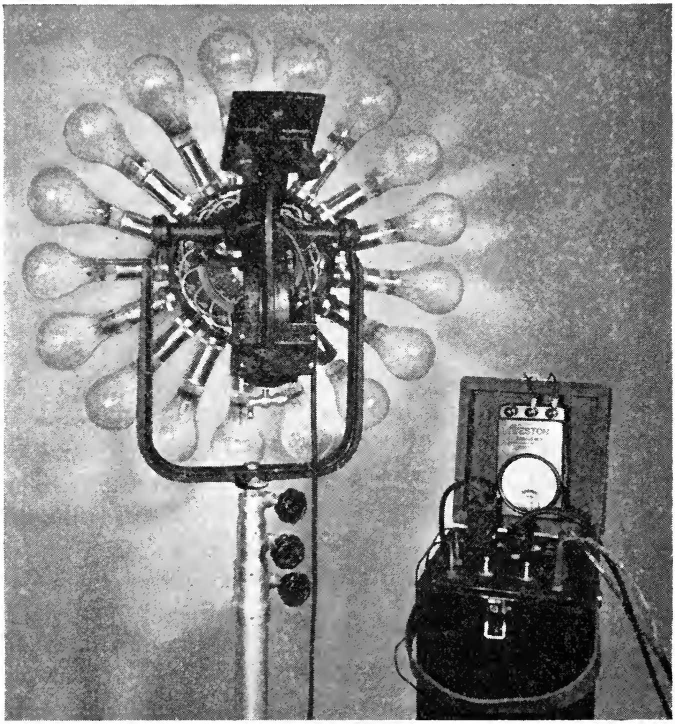


FIG. 6. Continuous flash lighting unit with parabolic reflector removed, and control box with ohmmeter used to check flash lamp circuits.

deed, the lamp does not fail to fire. To minimize chances for such failures, all wiring is heavier than actually necessary to carry the flashing current. Contact brush and commutator bars are quite large for the load. However, excessive resistance in any of the 17 lamp circuits may be present because of (*1*) improper seating of a lamp in its socket, causing defective contact, (*2*) corroded or fouled lamp base tip, or (*3*) a defective or damaged lamp.

Since the high-speed camera used in these tests has only one Microswitch for the making or breaking of an external electric circuit, the control unit further provides means for firing the lamps and starting the action of the subject before the camera in any predetermined order. This is accomplished by a "delaying" mechanism The contact made by the camera Microswitch releases a rotating, spring-loaded cam. The cam, in turn, operates a second Microswitch after rotating through an adjustable part of a revolution. The number of degrees through which the cam rotates before making contact is adjustable through a range of approximately 60 milliseconds. This device may accordingly be used to (*1*) start the flashing lamps before the action to be photographed, (*2*) start the action of the subject before the lamps, to allow it to reach its operational speed, or (*3*) operate the 2 flashing lamp units at varying time intervals instead of having them light up simultaneously.

FIG. 7. Continuous flash lighting unit with "power patch" and control boxes.

High-Speed Cinematography with Continuous Flash Lighting Units.—High-speed camera work is considerably simplified with continuous flash lighting units. Aside from the convenience of having the power supply for the unit completely contained within the unit, and portable (only sufficient 115-v a. c. is needed to operate the small synchronous motor of $^1/_{150}$ hp, which can be obtained from any household electric outlet), the absence of heat and of heavy cables and bulky lightstands greatly simplifies operation.

Photographically, a 3,000,000-lumen level of light is maintained long enough to expose 60 ft or more of film at 3000 frames per sec. Two units provide enough light to illuminate amply an average subject for exposure in black-and-white at lens apertures ranging from *f*/4 to *f*/8, depending upon conditions.

Although the flashing units can be safely placed within a few inches of the subject, it has been found convenient not to crowd the subject by placing them nearer than 3 ft. It is almost always important to have free access to the subject before and after it has been photographed. The high color temperature of flash lamps (3800 K) increases the efficiency of illumination for black-and-white work.

For use with color films, such as Ansco Color, tungsten type, or Kodachrome, type *A*, continuous flash lighting units afford sufficient illumination for exposures at 3000 frames per sec at lens stops of *f*/2.7 to *f*/4, depending upon conditions.

It is believed that many users of high-speed cameras currently available will find continuous flash lighting illumination of considerable interest. Also, it is possible that as improvements are made in this method of illumination, cameras attaining even higher speeds of operation will be introduced. It is hoped that broader acceptance of the continuous flash lighting method for high-speed camera work, resulting in great consumption of flash lamps of this type, will induce makers of flash lamps eventually to design them specifically for use in continuous flashing. Then the peaks and valleys of the total light output can be minimized, and, particularly for color films, this method of illumination will provide both the quantity, quality, and evenness of light output so desirable.

REFERENCES

EASTMAN KODAK CO.: "An Extensive Bibliography of High-Speed Photography."

BOON, J. L.: "The Eastman High-Speed Camera, Type III," *J. Soc. Mot. Pict. Eng.*, **43,** 5 (Nov., 1944), p. 321.

EDGERTON, H. E., AND GERMESHAUSEN, K. J.: "Stroboscopic-Light High-Speed Motion Pictures," *J. Soc. Mot. Pict. Eng.*, **XXIII**, 5 (Nov., 1934), p. 284.

EDGERTON, H. E.: "Stroboscopic and Slow-Motion Pictures by Means of Intermittent Light," *J. Soc. Mot. Pict. Eng.*, **XVII**, 3 (Mar., 1932), p. 356.

LESTER, H. M.: "Photoflash Lamps—Motion Pictures," *G.E. Review*, **47,** 4 (Apr., 1944), p. 19.

LESTER, H. M.: "A Special Problem in Time Microscopy," *J. Phot. Soc. of Am.*, **11,** 2 (Feb., 1945), p. 65.

PALME, A.: "Intense Light," *Amer. Phot.* (Jan., 1945), p. 17.

WATSON, E. M.: "Aids for Pictorially Analyzing High-Speed Action," *J. Soc. Mot. Pict. Eng.*, **43,** 4 (Oct., 1944), p. 267.

WATSON, E. M.: "Fast Motion Analysis as an Aid to Organized Invention," *J. Soc. Mot. Pict. Eng.*, **43,** 4 (Oct., 1944), p. 289.

WESTERN ELECTRIC CO.: "Western Electric Fastax High-Speed Motion Picture Camera," Instruction Bulletin No. *1079* (1943).

AUTOMATIC RECORDING OF PHOTOGRAPHIC DENSITIES*

J. G. FRAYNE AND G. R. CRANE**

Summary.—*The Western Electric 1100-type densitometer has been modified to permit direct recording of H and D curves and other photographic data. A special linear 80 db Speedomax recorder permits direct recording of densities from zero to 4.0.*

At the time of the original introduction of the Western Electric *RA-1100* densitometer,[1] some consideration was given to the possibility of providing a direct recording attachment to obviate the necessity of plotting characteristic H and D curves obtained from density readings of the step tablet sensitometer strip. However, since no suitable commercial recording device was available at that time, it was decided to introduce the instrument to the industry with direct reading facilities, leaving the recording feature to be incorporated at a later time whenever suitable equipment might be developed for this purpose. The instrument described in this paper was designed and built to meet the requirements of the Triplett and Barton X-ray Testing Laboratories, Burbank, California.

Anybody familiar with the use of a densitometer in a large production laboratory realizes the prodigious effort put forth in the plotting of H and D control strips and will readily agree that automatic plotting of these curves would not only save a great deal of labor, but would at the same time make possible much more accurate graphical representation of the data. Since density is a logarithmic function of film transmission, the output of the recording device must bear a logarithmic relationship to the transmission of the film. There are 2 possible methods of doing this: either by designing a densitometer amplifier to have a logarithmic response, that is, the output to be a logarithmic function of the input, or by using a linear amplifier and incorporating a logarithmic attenuator to control the movement of the recording device.

* Presented May 15, 1945, at the Technical Conference in Hollywood.

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

The relationship between decibel ratio and density may be deduced as follows:

Let T_1 = transmission of one silver deposit
Let T_2 = transmission of another silver deposit
By definition, the corresponding densities D_1 and D_2 are given by

$$D_1 = \log 1/T_1$$
$$D_2 = \log 1/T_2$$
$$\text{or } D_1 - D_2 = \log T_2/T_1$$

The decibel ratio of the light energy transmitted by the 2 deposits is given by

$$\text{db} = 20 \log T_2/T_1$$
$$\text{db} = 20\,(D_1 - D_2)$$
$$\text{For } D_1 = 4.0 \text{ and } D_2 = 0$$
$$\text{db} = 20 \times 4 = 80$$

Since the newer model, *1100A* densitometer, is designed to read densities from 0 to 4.0, the amplifier output would have to be proportional to the logarithm of input over an 80-db range. This is very difficult, if not impossible, to achieve with present techniques and, consequently, was abandoned early in the investigation. Fortunately, the Leeds and Northrup Company[2] had published an article describing a 40-db continuous recording Speedomax, the output as indicated by the position of the recording pen, bearing a linear decibel relationship to the input voltage to the recorder. Since it would be possible to record up to a maximum density of only 2.0 with this device, the Leeds and Northrup Company was asked to provide a modified Speedomax recorder with a linear 80-db range, thus permitting the recording of densities from 0 to 4.0.

In order to convert the *RA-1100* densitometer into a recording device, provision must be made for moving the sensitometer strip uniformly past the scanning beam. If the sensitometer strip is of the ordinary step tablet type exposed by means of an Eastman IIb sensitometer, a discontinuous curve would be plotted by the recording device. If a smooth H and D curve is to be obtained from the instrument, provision must of course be made for a continuously varying exposure in the sensitometer.

In the *RA-1100* densitometer modified for recording purposes, a specially designed high gain amplifier is bridged across the input of the standard densitometer amplifier. This permits the use of the standard instrument in a normal manner even with the addition of the recording attachment. The additional amplifier must be capable of delivering a sufficient voltage for operation of the Speedomax recorder. Thus, the amplifier output should be such that the recording pen will assume the zero density position with no film in the scanning gate. At the same time, the noise output of the amplifier must be so low that the recorder will go off scale on the high-density end when the light beam is completely blocked. Aside from a specially coupled network between the amplifier and the Speedomax unit itself, the modified densitometer requires the addition of the 2 separate items referred to above. These will now be described in some detail.

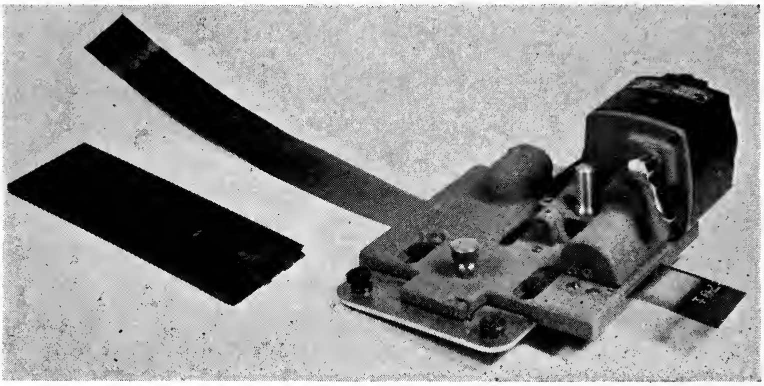


FIG. 1. *RA-1200* densitometer film moving mechanism.

FILM PULLING MECHANISM

A consideration of the problem of pulling film automatically, with a device to be applied to existing densitometers, led to the following requirements:

(*1*) If a continuously variable sensitometer strip is to be used, the scanning aperture must have its shortest dimension in the direction of the film travel.

(*2*) The film must be driven by a source which is synchronized with the paper drive of the Speedomax recorder.

(*3*) The film must be controlled in a manner which will provide for rapid and convenient operation and also insure accurate density measurements by the densitometer.

The optical system of the densitometer is such that the scanning beam cannot be readily rotated 90 degrees and, therefore, it seemed desirable to move the film toward the operator, which direction is at 90 degrees to the standard arrangement. This permits a continuously variable sensitometer strip to be scanned by an aperture which is 175 mils wide by either 16 or 65 mils in the direction of the film travel. A film drive unit was, therefore, developed to meet the above requirements, and arranged to replace the *T*-shaped film guide normally used with the densitometer. This device is shown by Fig. 1 and installed on the densitometer in Fig. 2. It consists of a film pulling assembly mounted on a base plate which is fastened to the densitometer panel by means of 4 thumbscrews. These may be quickly removed to permit the use of the standard film guide. The film drive is accomplished by a pair of rollers which propel the film by friction and it is designed to operate with film strips 35 mm in width. The upper roller is driven by a small synchronous motor with the proper

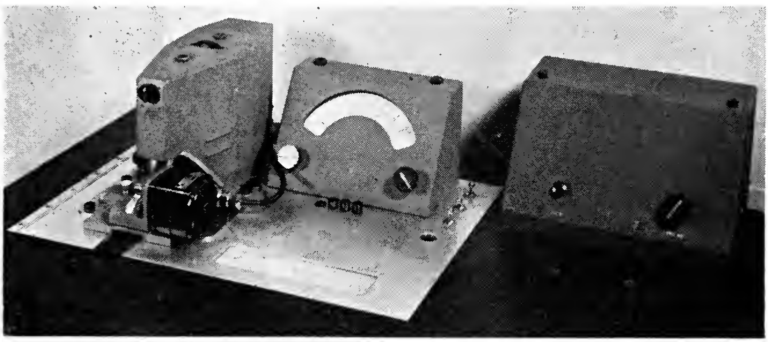


FIG. 2. *RA-1200* densitometer film moving mechanism and amplifier.

gearing to drive the film strip exactly 10 in. in 30 sec. A small lever on the front of the device is used to lift the upper roller so that the film strip may be inserted from the front. With the strip in the proper position required for scanning, the lever is lowered to contact the film and sufficient spring tension is provided to prevent slippage. The synchronous motor is connected to the same source of power as the Speedomax paper drive motor and both motors are started by the same switch. The accelerating times of the 2 motors are quite short and are sufficiently alike that no measurable error is introduced.

It is essential that good contact be maintained between the film emulsion and the scanning aperture plate of the densitometer. This is accomplished by 2 small spring-mounted rollers which bear on the film on both sides of the aperture. To protect the film from dirt or abrasion, a protective guide assembly is inserted in the slot under the densitometer head to receive the film as it is pushed in from the front. It is lined with plush and so constructed that it may be opened for cleaning.

For fast and convenient operation with this device, it is recommended that the continuously variable sensitometer strip conform to the requirements shown on Fig. 3. This proposed sensitometer scale is 10 in. long and starts at a punched hole which serves as an index which will register with the scanning beam as the operator places the strip in the instrument. This enables the operator to watch the meter of the densitometer which gives a zero or minimum reading when the punch mark is in exact register with the scanning

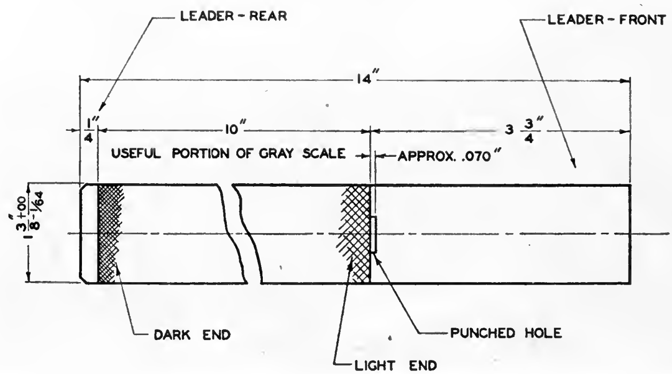


FIG. 3. Sensitometer strip specifications for use as *RA-1200* recording densitometer.

aperture. When this condition is attained, he drops the lever which engages the film with the driving roller and the device is then ready for use.

The film pulling assembly may be shifted laterally on its base plate by turning a knob so that the film may be scanned at any point to within $^3/_{16}$ in. of either edge. The scanning position is indicated by an index mark and scale as shown by the photograph. It is assumed that the X-ray sensitometer strips would normally be scanned at the center, but this facility is provided to accommodate other types of sensitometer strips such as those encountered in motion picture practice.

The densitometer must be slightly modified to accept this device, the modification consisting primarily of cutting an opening in the panel to clear the lower roller assembly of the film pulling mechanism. Four holes are tapped in the panel to accept the mounting thumb-screws and the slot in the head casting is widened to permit the lateral shift of the film. The *T*-shaped film guide is built out so that after modification, the densitometer may be used either with this device or in the normal manner, and it may be assembled or disassembled in 2 or 3 min.

AMPLIFIER

Since it is desirable to avoid the necessity of adding an extra power supply for the added amplifier, it was necessary to design the latter so

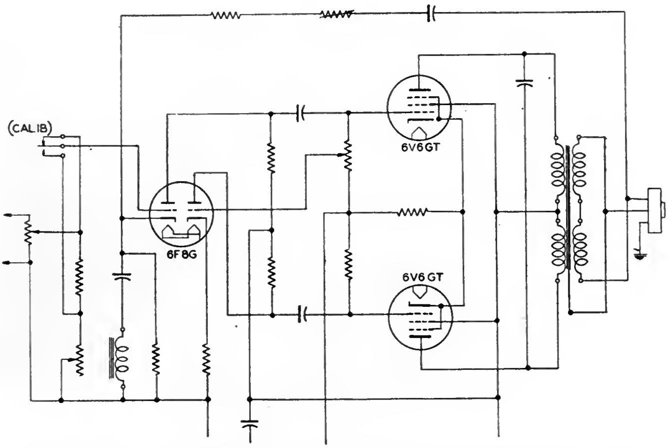


FIG. 4. Extra amplifier required to operate Speedomax recorder.

that it would operate satisfactorily from the power supply originally furnished with the densitometer. Since this power supply furnishes 180 v plate supply, vacuum tubes had to be selected and an output circuit designed to operate from it to furnish the necessary power for operating the recording unit. The amplifier is connected through a plug connection to a pair of input terminals of the densitometer amplifier, shown in Fig. 4. The first stage is a phase inverter for coupling to the output push-pull circuit, which utilizes a pair of *6V6* vacuum tubes. The gain of the amplifier is controlled by the potentiometer in the input circuit. Pressing the calibration button automatically inserts an 80-db loss into the amplifier for checking the 4.0 density point on the Speedomax scale. In addition to furnishing the necessary power to operate the Speedomax recorder, the amplifier must have a linear relationship between output and input over the 80-db range, and the signal-to-noise ratio must be of the order of 90 db. Both of these requirements have been substantially met.

The output of the amplifier described above is coupled through a high-pass filter and isolating transformer to the input of the Speedomax unit. The purpose of the high-pass filter is to attenuate low-frequency microphonic noises and a-c hum which would result in spurious readings. Since it is only necessary to transmit the 400-cycle frequency generated by the densitometer chopper wheel, the addition

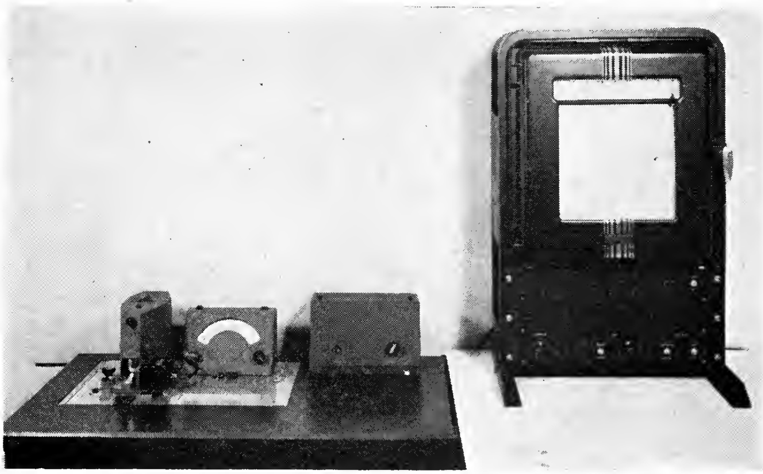


Fig. 5. Complete *RA-1200* recording densitometer.

of a low-pass filter cutting off sharply above this frequency would further enhance the signal-to-noise ratio of the system. However, the operation appears to be quite satisfactory without the addition of such a filter. The high-pass filter and isolating transformer are mounted on the framework of the Speedomax unit.

SPEEDOMAX RECORDER

The operation of the Speedomax recorder has been described elsewhere[2] so that it will not be necessary to go into any further detail here. For the benefit of those not familiar with the operation of this unit, it is only necessary to state that the device operates on the selfbalancing principle. To illustrate, assume that there is no film in the scanning gate and that the recorder indicates zero density. The insertion of any density in the gate reduces the input to the Speedomax unit. This disturbs the balance within the unit and causes a motor to drive the input logarithmic potentiometer to a new position at which the balance is again restored. The same motor which drives the attenuator also drives the recording pen, and since the movement

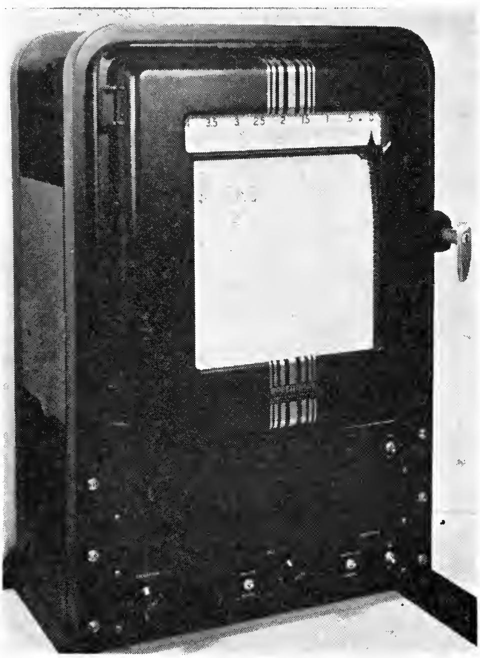


FIG. 6. Speedomax recorder associated with *RA-1200* recording densitometer.

of the attenuator arm is linear in decibels, the movement of the pen will also be linear in decibels or density. If a density of 4.0 is inserted in the scanning gate, the pen will move across the paper from the position of zero density to that of 4.0. For any intermediate value of density, the pen will stop at the appropriate position on the scale. The recorder has sufficient speed and damping that it will record an abrupt full-scale change in less than 2 sec without overshooting.

The paper chart on which the photographic characteristics are recorded is driven by a synchronous motor insuring that the paper moves at the same speed as the film being drawn past the scanning aperture. Since the log exposure axis is parallel to the direction of the movement of the paper, the scale will be determined by the linear speed of the latter. While it is desirable that the density scale across the paper be identical with the log E scale, in order to permit direct reading of contrast or gamma, it is not essential since the value of

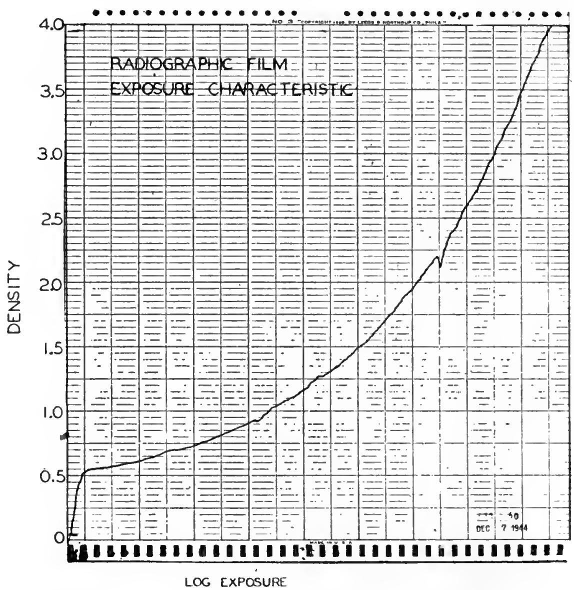


FIG. 7. Relationship between density and exposure on a radiographic film.

gamma may be obtained from a suitably engraved template. In the present instrument the log E scale extends over a distance of 10 in.

Fig. 5 shows a photograph of the complete densitometer with recording attachment, while Fig. 6 is a photograph of the Speedomax recorder alone. Fig. 7 is a chart made by Triplett and Barton showing the relationship between density and exposure on a radiographic film. In this case the exposure on the film is made through a triangular shaped wedge of metal so that a continuously varying log exposure scale is achieved. The complete chart was made in 30 sec.

The recording sensitometer described in this paper has been in service for several months and has proved to be very reliable in operation, as well as rendering a true graphical representation of the photographic characteristics under investigation. Its extended use in the future will largely eliminate the time-consuming plotting of H and D curves and other photographic characteristic data, thus adding to the production value of the *RA-1100* type densitometer.

REFERENCES

[1] FRAYNE, J. G., AND CRANE, G. R.: "A Precision Integrating Sphere Densitometer," *J. Soc. Mot. Pict. Eng.*, **XXXV**, 2 (Aug., 1940), p. 184.

[2] CLARK, W. R.: "The 'Speedomax' Power-Level Recorder," *Trans. A. I. E. E.*, **59** (Dec., 1940), p. 957.

VARIABLE-AREA RELEASE FROM VARIABLE-DENSITY ORIGINAL SOUND TRACKS*

JOHN P. LIVADARY AND S. J. TWINING**

Summary.—*The variable-density and variable-area systems of recording sound on film, with the many available forms of standard or push-pull tracks, enable the sound engineer to select the type of sound track best suited to his particular problems.*

A combination of 200-mil variable-density push-pull tracks for original recording and 100-mil variable-area standard tracks for theater release has been successfully employed by the Sound Department of Columbia Studios on a number of productions. This combination has been found to provide high output in the theater with low overall distortion values.

The processing of standard variable-area tracks in different release laboratories has long been a critical problem. A method is described which greatly simplifies the solution of this problem and which, in its application, has proved to be thoroughly practical under widely varying conditions.

The 2 fundamental systems of recording sound on film, namely, the variable-density and the variable-area systems, with the many available forms of standard or push-pull tracks, enable the recording engineer to select the type best suited to the conditions under which it is required to operate. Such a statement, of course, ignores the practical limitations which may be imposed by recording license agreements.

A combination of 2 such systems, the 200-mil variable-density push-pull system for studio recording, and the 100-mil standard variable-area system for theater release, has been used intermittently by the Sound Department of Columbia Studios for some time. This combination has provided us with greater latitude for the release of our sound than was available to us previously, and it appears to meet our recording requirements quite adequately. Since we contemplate standardizing on this combination eventually, the factors which have prompted this decision may be of interest. They are as follows:

The maximum signal-to-noise ratio of a system is determined by 2

* Presented May 15, 1945, at the Technical Conference in Hollywood.

** Columbia Pictures Corporation, Hollywood.

factors—the ceiling, or highest practical limit of modulation, and the threshold, or lowest practical limit of modulation. The ceiling is fixed by the amount of distortion that can be tolerated at high modulations, and the threshold is determined by the highest permissible noise level.

Considering the 200-mil push-pull type of variable-density recording, we note that the 200-mil width, plus the application of normal noise reduction, pre- and post-equalization, and the use of fine-grain film stocks, has increased the signal-to-noise ratio of this system to a figure well over 50 db which, in our opinion, is quite adequate for studio recording purposes. Reduction of second harmonic distortion through action of the push-pull system and the use of limiters to prevent the highest modulations from intruding excessively into the nonlinear portion of the film characteristic have resulted in a total harmonic distortion content for our operations that is not greater than $1^1/_2$ per cent, or an equivalent intermodulation value of 6 per cent. These values are based upon a 400-cycle signal modulated 80 per cent.

In choosing this system for studio recording we were, to a considerable extent, guided by our own ideas as to the desirable characteristics of a recording system. These ideas are based on the philosophy that it should be possible to faithfully register the original signal upon the recording medium with as little alteration as possible, preserving not only the essential elements of the normal frequency spectrum of the signal, but also its original volume range. The Western Electric 200-mil variable-density system has been found well suited to this purpose.

Another consideration which caused us to favor variable-density for studio recording is that we feel this type is somewhat safer from the film processing standpoint. In the event of unavoidable irregularities in the processing operations, the low modulations of the variable-density system do not suffer to the same extent as they do in the variable-area system, and in addition the density tracks are less affected by the dirt and scratch noise of the film.[1]

Certain differences exist between the requirements of original recording and those which govern the release of the sound for use in the theater. This necessitates a considerable alteration of the original product which can be suitably carried out during the rerecording operations. One of the chief requirements of the release system is that it must have adequate output so that the highest passages of music can be successfully reproduced without adding materially to the distortion that already exists in the original material. Release prints should also be capable of playing close to the average fader setting of the theater toward which most projectionists normally gravitate.

We find that the 100-mil standard variable-area system offers an excellent medium for this purpose. If we compare the output of a standard area track with that of an equivalent density track, we find that the output of the area track is 7 db higher, which places it on a par with the output of the 200-mil push-pull density track used for studio recording. It is a recognized fact that, for the same film output, the variable-area track has less distortion than the corresponding 100-mil variable-density track which must be overloaded by 7 db in order to obtain an equivalent output.

Our experience with the 100-mil variable-area sound track has been limited to results obtainable from the Western Electric 200-mil variable-area modulator described by Benfer and Lorance.[2] We have used half of the 200-mil sound track obtained from this Class *A* push-pull modulator as a standard release track. Tests with this modulator, using an input of 400 cycles at 80 per cent modulation, have shown that the distortion of the original 200-mil push-pull density recording is not increased by more than one per cent total harmonics in rerecording to 100-mil area release track. This places the over-all distortion of the release product at not more than $2^1/_2$ per cent total harmonics when measured with the General Radio Harmonic Analyser.

The variable-area system is excellently adapted to handling reasonable excursions into the overload region when rerecording the sound effects used in release. Here, the increased amount of distortion resulting from the overload is not objectionable and the satisfaction resulting from the increased output is very gratifying.

Mueller[3] and Fletcher[1] have shown that the volume range of the release track must be reduced on account of the higher threshold of noise encountered in theaters. This correction is conveniently supplied in the variable-area system by means of the electronic compressor. We find that a fixed amount of compression of the order of 3 to 5 db into 25, in addition to the normal manual compression resulting from the habits of our rerecording mixers, is adequate for the transfer of the variable-density originals to variable-area release tracks.

It is interesting to note that, in our procedure, the small amount of fixed compression supplied by the electronic compressor is introduced past the point of monitoring in the rerecording channel and is consequently inaudible to the rerecording mixer. Later, when the mixer hears his work reproduced in the theater, he is satisfied with the values of the return. We have interpreted this as an indication that the noise level of our dubbing stage is lower than that encountered in the average theater and that this method of introducing the required amount of fixed compression is thoroughly satisfactory once the basic noise level relationships between the dubbing stage and theater have been established by practical observation.

The advantages possessed by the variable-area track when used for release must be weighed against certain disadvantages. For instance, extremely low modulations may, at times, result in "blastiness" if the modulations happen to ride on a poorly illuminated portion of the scanning slit. This condition may be remedied to some degree by masking off one-half of the bilateral track and simultaneously increasing the level of the signal by 6 db for such portions of the rerecording that require very low level output. This technique was originally employed in the Sound Department of Columbia Studios and has been patented.

Our experience in the use of the variable-area system as the medium of release has brought to our attention the fact that the means of determining optimal processing conditions, through the use of the modulated high-frequency method as described by Baker and Robinson,[4] does not provide an adequate solution for the problems arising out of the great variety of developing and printing conditions encountered in the various release laboratories. At times, particularly in connection with the rerecording of sharp sibilants, we have had great difficulty in establishing processing conditions for the area tracks that would resolve these sibilants satisfactorily despite the fact that we were able to show cancellations of the order of 45 to 55 db by the modulated high-frequency method.

In an effort to surmount this difficulty, we have established a method of determining optimal processing conditions which we have designated as a Sibilant Pattern Test. Although this method has not as yet been theoretically analyzed so that it might be presented in formal manner, it has proved so practical in solving our processing problems that, pending its theoretical investigation which is at present under way, we would like to present it in its practical form as it is now used. The test is carried out quite simply and involves no greater effort than is required to make the modulated high-frequency test. It has the advantage, however, that no special equipment is required and the determinations can be made wherever standard projection equipment is available. The test may be carried out as follows.

A short piece of original recording is selected which contains several moderately overloaded sibilants abundant in frequencies at the extreme upper range of the reproduced spectrum. A print containing about 10 ft of this material is made into a loop with an interval of unmodulated track between the ends. The loop is then placed in the projection machine and the test dialogue is rerecorded continuously at a series of lamp currents separated by intervals of $^1/_{10}$ amp. A continuous negative is thus created containing a series of recordings of the dialogue material in the loop, each one of which will be at a different negative density.

In order to obtain the required information on negative densities, the loop is made up with sufficient unmodulated spacing between the ends of the dialogue to permit the recording of unbiased sections suitable for making density measurements. The negative is then developed at the standard speed and gamma which has been established for this purpose and which will be maintained for all subsequent development runs governed by this test. After completion of this operation, the negative is then used to make a series of prints of about 5 different densities spread out over the useful printing range. Upon completion of the prints they are identified and the density of each is measured and recorded.

It is obvious from the above that a sibilant pattern test can be set up which, with suitably spaced intervals, will cover all practical combinations of negative and print densities within the limits of the recording and printing equipment.

A form similar to that shown in Fig. 1 may now be marked off on a sheet of paper with the measured negative densities listed in a vertical column and the print densities listed horizontally. A space is provided in the included form in which to record the goodness of each combination of negative and print densities. The prints are assembled in the order of running to correspond with the form sheet and then projected in the review room. As each section is reproduced it is judged for its ability to resolve the sibilants of the test material, and each section is given a relative rating using some such convenient symbols as *VG* for very good, *G* for good, *F* for fair, *B* for bad, and *VB* for very bad.

The tabulated results of the test may then be transferred to a graph, shown in Fig. 2, on which the ordinates are print densities and the abscissae are negative densities. The symbols *VG, G, F, etc.*, are then marked on the graph sheet at the positions corresponding to their associated negative and print densities and a straight line is drawn so as to satisfy the positions of highest rating, such as the points of *VG* if such are used, but also with due regard to satisfying the conditions of falling approximately in the mid-position of the *F* points, for example, if this symbol has been used to denote the lower limit of what might be considered an acceptable treatment of the

NEGATIVE DENSITY	PRINT DENSITY			
	1.18	1.28	1.40	1.48
3.45	B	B	B	F+
3.30	B−	F	F+	G
3.20	B−	F+	G−	G+
3.09	F	G−	G	G
2.93	G−	G	G	G−
2.75	VG	G−	G−	F
2.42	G−	F−	F−	VB

FIG. 1. Form for Sibilant Pattern Test.

sibilant. It is obvious that the lines denoting the outer limits of acceptable treatment also are indicative of the tolerence inherent in the system of processing under examination, and thus serve a very useful purpose for comparison with other systems that may be examined.

It may seem at first glance that the method employed in the test, of listening and grading the results, would not offer the precise determinations that are obtained by a system of instrumental measurements such as would be the case in the use of the modulated high-frequency method of testing. While this may be true in comparing the results of tests made under widely separated intervals with unrelated material, the sibilant pattern test nevertheless has proved to be extremely practical, not only in the ease with which a competent technician can rate the sections and complete the pattern sheet, but also in the thorough practicability of the results as applied to the actual production work carried out under the specifications thus established.

As in the case of the modulated high-frequency test method, the data of the sibilant pattern test so far tabulated do not permit the selection of any optimum combination of negative and print densities from the infinite number of favorable combinations contained within the limits of the pattern. Such optimum values may be determined, however, by further editing the prints so that they contain only those sections which have previously been given the arbitrary auditory

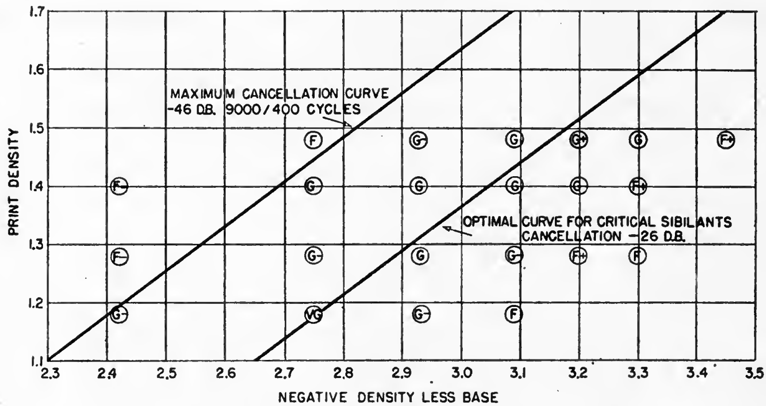


FIG. 2. Optimal processing curves for variable-area recording negatives on Eastman *1371* stock. Prints on Eastman *1302* stock. Negatives and prints exposed with unscreened tungsten.

ratings of *G* and *VG*, or whatever ratings have been applied to the combinations of best resolution under the circumstances of the test.

These edited tests are then assembled, reviewed, and given comparative ratings, a task which is greatly simplified by the elimination of the inferior material. Optimum values of negative and print densities may thus be determined. If the highest rated combinations under this examination do not show a sufficient difference so that they may be rated among themselves, it may be concluded that the optimum position is noncritical and suitable conditions of matched negative and print densities may be selected based on practical considerations affecting the operation of the printers and recorders.

When it is desired to compare the results of the sibilant pattern test with those of the modulated high-frequency test, both tests may be made consecutively on the same piece of negative stock.

Such comparative tests have been carried out. The results of these tests have shown that, in the several cases which were examined, the slope of the graph relating suitable negative and print densities as determined by each method of testing was the same. In certain ideal cases, in which excellent developing and printing conditions with ultraviolet exposures were available, the graphs of the 2 tests coincided exactly. Under other circumstances, presumably where less suitable conditions of processing obtained, the lines for the optimal combinations on the graph sheet were widely displaced. These separations have been found to be as high as 0.40 in print density in some cases. Under such circumstances, when the specifications for the film processing were set up on the basis of the modulated high-frequency tests, the practical application of these values resulted in failure to resolve the sibilants adequately. On the other hand, when the specifications were based on the results of the sibilant pattern tests, the practical operations resulting from the use of the values thus determined were found to be entirely successful.

It has also been found useful to rerecord the sibilant test loop at the end of each reel intended for release. When printed, the quality of this end test immediately certifies the condition of the reel as a whole. To obtain final and precise print densities suitable for release printing, the sibilant tests may be removed from the end of each release negative, properly identified, and spliced together into a single roll. The roll of negative can then be printed to 4 or 5 different densities. The prints are projected and each section given a quality rating. Coordination of these data permits a precise determination to be made for the most suitable print density for each reel. This end test is also useful in the case where a single reel may be designated for release in a laboratory where the optimal processing conditions have not been determined by a sibilant pattern test. In such a case, the end test can be used and a determination made for the best print density with the minimum amount of time and expense and without the use of special equipment.

Actually, the sibilant pattern test, which from its nature bears directly upon the practical solution of the sibilant problem in variable-area processing, has proved to be thoroughly reliable and we now use it in preference to the modulated high-frequency method in the determination of optimal processing values for negatives and prints.

REFERENCES

[1] FLETCHER, H.: "The Stereophonic Sound-Film System—General Theory," *J. Soc. Mot. Pict. Eng.*, **XXXVII**, 4 (Oct., 1941), p. 331.

[2] BENFER, R. W., AND LORANCE, G. T.: "A 200-Mil Variable-Area Modulator," *J. Soc. Mot. Pict. Eng.*, **XXXVI**, 4 (Apr., 1941), p. 331.

[3] MUELLER, W. A.: "Audience Noise as a Limitation to the Permissible Volume Range of Dialogue in Sound Pictures," *J. Soc. Mot. Pict. Eng.*, **XXXV**, 1 (July, 1940), p. 48.

[4] BAKER, J. O., AND ROBINSON, D. H.: "Modulated High-Frequency Recording as a Means of Determining Conditions of Optimal Processing," *J. Soc. Mot. Pict. Eng.*, **XXX**, 1 (Jan., 1938), p. 3.

SOCIETY ANNOUNCEMENTS

JOURNAL AWARD

The 1945 Journal Award, given annually for the most outstanding paper originally published in the JOURNAL during the preceding year, was awarded to C. J. Kunz, H. E. Goldberg, and C. E. Ives for their paper "Improvement in Illumination Efficiency of Motion Picture Printers." President D. E. Hyndman presented the recipients with inscribed parchment certificates at the Dinner-Dance held on October 16 during the 58th Semi-Annual Technical Conference at the Hotel Pennsylvania, New York.

The paper was published in the May 1944 JOURNAL and was first presented before the Society by the authors, all of Kodak Research Laboratories, Rochester, at the October 1942 Technical Conference in New York. A biographical sketch of the Journal Award winners is being prepared and will be published in an early issue of the JOURNAL.

FELLOW AWARDS

Announcement was made during the Technical Conference of the election of 10 Active Members of the Society to the grade of Fellow by action of the Board of Governors in recognition of their contributions to the advancement of the motion picture industry and of their services to the Society. Appropriate certificates were presented by President Hyndman to seven who were present at the Dinner-Dance on October 16. Those elevated are:

Lieut. Col. John O. Aalberg, formerly with RKO Studios, Hollywood.
Herbert Barnett, International Projector Corporation, New York.
John G. Bradley, Director, Motion Picture Project, The Library of Congress, Washington.
George L. Carrington, Altec Service Corporation, New York.
Major Lloyd T. Goldsmith, Director, Pictorial Engineering and Research Laboratory, Signal Corps Photographic Center, Long Island City.
Charles F. Horstman, RKO Service Corporation, New York.
Charles E. Ives, Eastman Kodak Company, Rochester.
C. L. Lootens, Paramount Pictures, Inc., Hollywood.
G. T. Lorance, International Projector Corporation, New York.
Jack A. Norling, Loucks and Norling Studios, New York.

AMENDMENTS OF BY-LAWS

Proposed amendments of By-Laws I, VII, and XI of the Constitution and By-Laws of the Society, as published on page 246 of the September JOURNAL, were discussed and voted on by qualified members present at a general business session of the Society on October 15 during the recent Technical Conference at the Hotel Pennsylvania, New York. All were approved and are now in effect.

OFFICERS, GOVERNORS, AND SECTION MANAGERS FOR 1946–47

As a result of the recent elections, the following is a list of the Officers and Governors of the Society for terms beginning January 1, 1946:

* *President:* DONALD E. HYNDMAN
* *Past-President:* HERBERT GRIFFIN
* *Executive Vice-President:* LOREN L. RYDER
** *Engineering Vice-President:* J. A. MAURER
* *Editorial Vice-President:* ARTHUR C. DOWNES
** *Financial Vice-President:* M. RICHARD BOYER
* *Convention Vice-President:* WILLIAM C. KUNZMANN
* *Secretary:* CLYDE R. KEITH
* *Treasurer:* EARL I. SPONABLE

Governors from the Atlantic Coast Area:
** FRANK E. CARLSON — * J. I. CRABTREE
** ALAN W. COOK — ** PAUL J. LARSEN
* REEVE O. STROCK

Governors from the Pacific Coast Area:
* CHARLES R. DAILY — ** WESLEY C. MILLER
** JOHN G. FRAYNE — * PETER MOLE
* WILLIAM A. MUELLER

Officers and Managers of the Atlantic Coast Section for terms beginning January 1, 1946, are:

* *Chairman:* FRANK E. CAHILL, JR.
* *Past-Chairman:* CLYDE R. KEITH
* *Secretary-Treasurer:* JAMES FRANK, JR.
Managers: ** HERBERT BARNETT — ** JACK A. NORLING
** HOLLIS D. BRADBURY — * W. H. OFFENHAUSER, JR.
* G. T. LORANCE — * H. E. WHITE

Officers and Managers of the Pacific Coast Section for terms beginning January 1, 1946, are:

* *Chairman:* HOLLIS W. MOYSE
* *Past-Chairman:* CHARLES W. HANDLEY
* *Secretary-Treasurer:* SIDNEY P. SOLOW
Managers: ** G. M. BEST — * F. L. EICH
* J. W. BOYLE — * H. W. REMERSCHEID
** P. E. BRIGANDI — ** G. E. SAWYER

PACIFIC COAST SECTION

One of the largest attended meetings of the Pacific Coast Section of the Society was held on September 25 when Major Roy Seawright and Warrant Officer

---

* Term expires December 31, 1946.
** Term expires December 31, 1947.

Jack R. Glass discussed the preparation of briefing films used by B-29 bomber crews. These films, which were made by the First Motion Picture Unit at Culver City under the direction of Major Seawright, and which played a vital role in pin-point bombing, showed the crews how their course to and over Japan appeared from the plane, through the bombsight, and on the radar screen.

The briefing films had to be made quickly and accurately without resorting to reconnaissance flights over Japan which might endanger the missions by revealing intended routes. Warrant Officer Glass described the project in detail and told of creating a large reproduction of Japan which was photographed to simulate the appearance of Japanese territory under flight. Samples of the films were screened.

As the second feature of the meeting, the German musical color motion picture, *Lady of My Dreams*, was exhibited. This picture, produced in 1942 using Agfacolor, was of interest to Section members and guests because it demonstrated the use of an integral tripack color system for 35-mm release prints with sound. The print was obtained through the courtesy of the Army Pictorial Service and the Academy of Motion Picture Arts and Sciences.

The meeting was held on the scoring stage of RCA Victor in Hollywood.

OCTOBER TECHNICAL CONFERENCE

The 58th Semi-Annual Technical Conference held in New York on October 15–17 was the most successful meeting ever conducted by the Society. Over 300 registrations were recorded for the 3-day Conference which required 7 technical sessions to present all the papers submitted to the Papers Committee. Individual sessions were well attended and interest in all papers presented was unusually enthusiastic.

Because of the decision of the Board of Governors to hold a regular national meeting following V-J Day, instead of a local metropolitan area meeting as planned previously, there were necessarily some changes made in the scheduling of papers as listed in the final printed program. Therefore, in answer to many requests which have been received for copies of the program, the editors are publishing in this issue of the JOURNAL the complete program as followed for the 3-day Conference. All technical sessions were held in the *Salle Moderne* of the Hotel Pennsylvania, New York.

Program

Monday, October 15, 1945

2:00 p.m. Opening Session of Conference.

Clyde R. Keith, *Chairman*

Session opened with a 10-min pre-release 35-mm motion picture short.

Welcome by President Donald E. Hyndman.

Report of the Convention Vice-President, W. C. Kunzmann.

"The Waller Flexible Gunnery Trainer," by Fred Waller, Vitarama Corp., Long Island City, N. Y.

"A Wide Angle 35-Mm High-Speed Motion Picture Camera," by J. H. Waddell, Bell Telephone Laboratories, New York.

"Nonintermittent Motion Picture Projector with Variable Magnification," by F. G. Back, Research and Development Laboratory, New York.

"A New 16-Mm Buzz Track Recorder," by M. G. Townsley, Bell and Howell Co., Chicago, Ill.

"Use of the 16-Mm Motion Picture in the Educational Reconditioning of Hospitalized Combat Veterans," by E. W. Schultz, Army Medical Center (Walter Reed General Hospital), Washington, D. C.

"A Film Splicing and Repair Machine," by Armour Wallingsford, Republic Studio, North Hollywood, Calif.

"A Laboratory Film Ink," by Armour Wallingsford, Republic Studio, North Hollywood, Calif.

"A National Film Library—The Problem of Selection," by J. G. Bradley, Director, Motion Picture Project, The Library of Congress, Washington, D. C.

8:00 p.m. Evening Session.

Nathan D. Golden, *Chairman*

Session opened with a 10-min pre-release 35-mm motion picture short.

Talk on I. G. Farben Afga Color by Lt. Col. R. H. Ranger, U. S. Army Signal Corps, on behalf of the U. S. Technical Industrial Intelligence Committee. Program was sponsored by the U. S. Department of Commerce.

Tuesday, October 16, 1945

10:00 a.m. Morning Session.

Earl I. Sponable, *Chairman*

Session opened with a 10-min pre-release 35-mm motion picture short.

"The Use of Desiccants with Undeveloped Photographic Film," by C. E. Ives and C. J. Kunz, Eastman Kodak Co., Rochester, N. Y.

"Measurement and Control of Dirt in Motion Picture Processing Laboratories," by N. L. Simmons, Eastman Kodak Co., Hollywood, and A. C. Robertson, Eastman Kodak Co., Rochester, N. Y.

"Aluminum and Chromium as Gelatin Hardeners," by H. L. Baumback and H. E. Gausman, Paramount Pictures, Inc., Hollywood.

"An Application of Direct-Positive Sound Track in 16-Mm Release Processing by Duplication Method," by Major G. C. Misener and G. Lewin, Signal Corps Photographic Center, Long Island City, N. Y.

"A Simplified All-Purpose Film Recording Machine," by G. R. Crane and H. A. Manley, Electrical Research Products Division, Western Electric Company, Hollywood.

2:00 p.m. Afternoon Session.

Herbert Griffin, *Chairman*

Session opened with a 10-min pre-release 35-mm motion picture short.

"The Wartime Record and Post-War Future of Projection and Sound Equipment," by A. G. Smith, National Theatre Supply, New York.

"Carbon Arcs for Motion Picture and Television Studio Lighting," by F. T. Bowditch, M. R. Null and R. J. Zavesky, National Carbon Co., Cleveland, Ohio.

"Westrex Standard Sound Film Reproducer," by G. S. Appelgate, Western Electric Export Corporation, New York, and J. C. Davidson, Electrical Research Products Division, Western Electric Company, Hollywood.

"Westrex Master Sound Film Reproducer," by G. S. Appelgate, Western Electric Export Corporation, New York, and J. C. Davidson, Electrical Research Products Division, Western Electric Company, Hollywood.

"Projection Equipment for Review Rooms," by H. J. Benham, Radio Corporation of America, RCA Victor Division, Camden, N. J.

"Specialized Photography Applied to Engineering in the Army Air Forces," by Major P. M. Thomas and Capt. C. H. Coles, Air Technical Service Command, Wright Field, Ohio.

"A Loudspeaker for Critical Monitoring," by Major P. W. Klipsch, Southwestern Proving Ground, Hope, Ark.

"An Absolute Method for the Determination of the Effective *f* Stop Calibration of Camera Lenses," by C. R. Daily, Paramount Pictures, Inc., Hollywood.

"A Test Reel for Television Broadcasting Stations," by M. R. Boyer, Photo Products Div., E. I. du Pont de Nemours & Co., Parlin, N. J.

8:30 p.m. *Georgian Room*: **Fifty-Eighth Semi-Annual Dinner-Dance.**

President Donald E. Hyndman, presiding.

Introduction of Officers-elect for 1946.
Presentation of certificates to Fellows-elect.
Presentation of Journal Award for 1945.
Music and entertainment until 1:30 a.m.

Wednesday, October 17, 1945

10:00 a.m. Morning Session.

Major Lloyd T. Goldsmith, *Chairman*

Session opened with a 10-min pre-release 35-mm motion picture short.

"The Dual Projector," by T. C. Hoad, General Theater Supply Co., Toronto, Canada.

"A Simplified Recording Transmission System," by F. L. Hopper and R. C. Moody, Electrical Research Products Division, Western Electric Co., Los Angeles, Calif.

"A Brief for Film in Television," by John Flory, of Grant, Flory and Williams, New York.

"A Complete Motion Picture Production Plant for Metropolitan New York," by R. B. Austrian, RKO Television Corp., New York.

"The Illusion of Depth in Motion Pictures," by Lt. H. T. Souther, U. S. Army Signal Corps, Long Island City, N. Y.

"Theory and Practice of Lighting for the Camera," by Lt. H. T. Souther, U. S. Army Signal Corps, Long Island City, N. Y.

2:00 p.m. Afternoon Session.

E. Allan Williford, *Chairman*

Session opened with a 10-min pre-release 35-mm motion picture short.

"Report of the SMPE Color Committee," by J. A. Ball, Chairman, Hollywood.

"The Printing of 16-Mm Kodachrome Duplicates," by R. M. Evans, Eastman Kodak Co., Rochester, N. Y.

"An Improved Film Drive Filter Mechanism," by C. C. Davis, Electrical Research Products Div., Western Electric Company, Hollywood.

"The Ansco Colorpak Process for Professional Motion Pictures," by H. H. Duerr and H. C. Harsh, Ansco, Binghamton, N. Y.

"Phototube for Dye Image Sound Track," by A. M. Glover and A. R. Moore, Radio Corporation of America, Lancaster, Pa.

"Preliminary Sound Recording Tests with Variable-Area Dye Tracks," by R. O. Drew and S. W. Johnson, Radio Corporation of America, RCA Victor Division, Indianapolis, Ind.

"The Behavior of a Blue-Sensitive Phototube in Theater Sound Equipment," by J. D. Phyfe, Radio Corporation of America, RCA Victor Division, Indianapolis, Ind.

8:00 p.m. Evening Session.

Glenn E. Matthews, *Chairman*

Session opened with a 10-min pre-release 35-mm motion picture short.

"The Problem of Amateur Color Photography," by R. M. Evans, Research Laboratories, Eastman Kodak Co., Rochester, N. Y.

• *Note: This was a one hour and forty-five minute semi-popular lecture and demonstration on color photography.*

Adjournment of Fifty-Eighth Semi-Annual Technical Conference, by D. E. Hyndman, President.

EMPLOYMENT SERVICE

POSITIONS OPEN

Designer and engineer experienced in optics, lighting, and microphotography, capable of designing microfilm reading equipment and products related to microfilm industry. Reply to Microstat Corporation, 18 West 48th St., New York 19, N.Y.

Design engineer, experienced in mechanics and optics of motion picture cameras, projectors, and film scanning. Give details. Reply to Mr. John H. Martin, Columbia Broadcasting System, Inc., 485 Madison Ave., New York 22, N.Y.

POSITIONS WANTED

Sound recording engineer, 16- or 35-mm equipment, studio or location work, single or double system. Free to travel. For details write J. J. K., 354 Ninth Ave., New York 1, N.Y.

Honorably discharged veteran with 15 years' experience in all phases of motion picture production, including film editing, directing, producing. For details write F. A., 30-71 34th St., Long Island City 3, N.Y. Telephone AStoria 8-0714.

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

Director of visual training aids, now concluding government work, desires position with educational, industrial or commercial organization, supervising or assisting in the production or distribution of visual training or allied work. Write H. C. B., 348 Maryland Ave., Dayton 4, Ohio.

Chief Engineer of motion picture camera manufacturer now available. Special training in optics, electricity, electronics, mechanics. Experienced in all phases of manufacture of cameras, projectors, and accessories. Prefer West Coast, but not essential. Write Robert Winkler, 119 West 78th St., New York, N. Y.

MEMBERS OF THE SOCIETY
LOST IN THE SERVICE OF
THEIR COUNTRY

FRANKLIN C. GILBERT

ISRAEL H. TILLES

MORGAN L. HOBART

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 **DECEMBER, 1945** **No. 6**

CONTENTS

Indexes to the semi-annual volumes of the JOURNAL are published in the June and December issues. The contents are also indexed in the *Industrial Arts Index* available in public libraries.

JOURNAL
OF THE
SOCIETY of MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA • NEW YORK 1, N.Y. • TEL. PENN. 6 0620

HARRY SMITH, JR., EDITOR

Subscription to nonmembers, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscription or single copies of 15 per cent is allowed to accredited agencies. Order from the Society at address above.
Published monthly at Easton, Pa., by the Society of Motion Picture Engineers, Inc.
Publication Office, 20th & Northampton Sts., Easton, Pa.
General and Editorial Office, Hotel Pennsylvania, New York 1, N. Y.
Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

Vol 45 DECEMBER, 1945 No. 6

REPORT OF THE SMPE COMMITTEE ON COLOR*

As the motion picture industry undertakes an ever-growing percentage of production in color, the matters of increasing present facilities, of opening up new facilities, and, above all, the removal of limitations and restrictions upon methods of operation, become of the utmost importance. The engineers and technicians of the industry need to look ahead and formulate the problems and possible solutions thereof, so as to be ready wisely to advise the executives and producers, who, it can be confidently predicted, will wake up to the problems rather suddenly.

It is from this point of view that the Color Committee of the Society of Motion Picture Engineers wishes to emphasize the importance to the industry of the new high sensitivity caesium-antimony phototubes which are to be described in detail in various technical papers at this Technical Conference.

In order to appreciate the significance of these cells it should first be realized that the great majority of dyes which can be used in the production of color film are transparent to the near infrared region of the spectrum and consequently are unsuitable for use as components of the sound track, if, as is currently the case, the standard photoelectric cell has its maximum response in that region. This remark applies equally to acid dyes such as are used in imbibition processes, to basic dyes as used in dye-toning processes, and to the insoluble dyes produced by the aid of color formers and color developers.

To be sure, there are a very few dyes or suitable pigments which are absorptive in the near infrared region—ferric-ferrocyanide (the usual iron-tone) is the outstanding example. If, then, ferric-ferrocyanide is used for the cyan component of the picture, a satisfactory track, absorptive in the infrared, can be produced simultaneously with the cyan picture component without the requirement of any special proc-

* Presented Oct. 17, 1945, at the Technical Conference in New York.

essing steps. Such prints and tracks have been widely used in the 2-color field, as, for example, in Cinecolor prints.

However, the methods which produce this iron-tone image cannot in general be used in the production of yellow and magenta images. Furthermore, the use of this pigment permits no choice whatever in the selection of the cyan component. The iron-toned image for the picture has to be accepted as it is. So as a general conclusion, it can be said that the picture components suitable for the imbibition process, the color-former processes, or for any process wherein the 3 components are treated in a common manner, cannot be used to form a satisfactory track absorptive to infrared rays.

This difficulty has been overcome in the past by producing the sound track in silver or a silver compound, either by a completely separate step, or by means of edge treatment of the film at some stage of the processing. As an example of the former method there is Technicolor's black silver track, and as an example of the latter there is Kodachrome's silver sulphide track. Now either of these methods results in added expense—in the latter case, because of the delicacy of the operation. The boundary of the area of action of the edge-treating fluid, whether applied to track alone or to picture alone, must be confined to a zone only 0.015 in. wide between track and picture, and the action of the fluid must be absolutely uniform across the zone of application with no variation in the vicinity of sprocket holes; yet agitation as a means of securing uniformity is obviously excluded. A delicate operation of this sort requires, on the one hand, careful control and, on the other hand, the constant threat of reduced yields and increased costs. Quite a number of patents have appeared describing various chemical and mechanical methods of performing this edge treatment.

But now, if the sensitivity of the phototube can be confined to the visible range, then the same components that are used to make up the picture can also be used to produce the track without the necessity of edge treatment. It was with this thought in mind that an earlier Color Committee (in 1937) called attention to the desirability of finding or producing such a tube. At about that same time a photosensitive alloy was discovered by a German investigator, which alloy, when illuminated by an incandescent tungsten lamp, has a peak of response well inside the visible range. Furthermore, when properly prepared, this alloy possesses very remarkable sensitivity.

The development of phototubes containing this alloy has apparently been considerably retarded by the war, though various constructions containing it have appeared in several countries. German-made tubes have been referred to in various articles in *Kinotechnik* and other German magazines, which have been abstracted in the *Kodak Monthly Abstract Bulletin* for November, 1943, and February, May, October, and December, 1944. A translation of one of these articles appeared in the SMPE JOURNAL for September, 1944. English-made tubes are described in the *Proceedings of the Physical Society* (London) for March, 1943, and also in an article in the *Journal of the British Kinematograph Society* for January, 1943. The U. S. patent on the alloy is now in the hands of the Alien Property Custodian and licenses are available to anyone at a nominal fee.

For use in projectors it seems most desirable to arrive at a phototube which will have about the same output as does the ordinary *Ag-O-Cs* tube. A tube which meets this requirement and which is mechanically and electrically interchangeable with the present *868* type has been developed by RCA and will be manufactured in quantities as soon as there is a commercial demand. This tube will be known as the *1P37*. It is to be expected that satisfactory tubes will be made available by other manufacturers.

Tubes of this new type appear to have some advantages over the *Ag-O-Cs* tube. For example, the sensitivity at shorter wavelengths makes possible a marked increase in resolution of the slit image. This, and related factors, are described in detail in the several papers which are scheduled for presentation later in the Conference. From the comments of those who have experimented with the new tubes, it appears that this new unit is a remarkably good tool and one which promises to have a widespread use. In fact, it is very much in order for this industry to consider the proposition to replace the present infrared sensitive phototubes in projectors with tubes of this new type. The merits of the new unit can be summed up by saying that had it been developed prior to the *Ag-O-Cs* tube there would not now be any thought of replacing the former with the latter; and this statement can be made without considering the new potentialities of the new tube for color sound tracks.

The chief merit of the *Ag-O-Cs* tube, then, is reduced to the fact that it is already in widespread use. But, for sound reproduction, the threat of obsolescence hangs over it.

The results made possible by the use of tubes of this new type with sound tracks on color film will be the subject of additional papers at this and subsequent Conferences. The way in which tracks of ferric-ferrocyanide and of silver sulphide react with the new tube also needs study. In this connection it should be noted that ferric-ferrocyanide is not nearly so transparent in the range of sensitivity of the new tube as are the great majority of dyes in the near infrared region. And it appears from preliminary tests that the iron-tone track can be adapted to the new tube.

The Color Committee wishes to stress the fact that in tubes of this new type we have a new and useful tool which opens up possibilities of simplification of processing of sound tracks on color film.

Considering the matter of prospective future replacement, the Committee wishes to stress the matter of interchangeability and standardization, particularly in the 35-mm field. There are apparently two different characteristic constructions, and it is not clear from published data whether or not there is a variation in spectral sensitivity between the two constructions.

If, as, and when new tubes of this description are adopted by the industry, such a change must be world-wide and accomplished with a minimum of confusion. The Committee recommends that the Society communicate with the British Kinematograph Society and other similar organizations in all countries, to the end that a norm of performance for such tubes be set up. This norm should apply to both the optical and electrical characteristics.

The Committee believes that in the first instance this prospective change-over need be considered only for 35-mm film. A change-over in the 16-mm field is a rather different matter and with regard to that the Committee has no recommendations at the present time.

Color Committee

J. A. BALL, *Chairman*

M. R. BOYER	R. M. EVANS	A. C. HARDY
G. A. CHAMBERS	J. L. FORREST	W. C. MILLER
L. E. CLARK	J. G. FRAYNE	L. L. RYDER
R. O. DREW	L. T. GOLDSMITH	J. G. WHITE
	A. M. GUNDELFINGER	

FILM—THE BACKBONE OF TELEVISION PROGRAMMING*

RALPH B. AUSTRIAN**

Summary.—*Based upon several years of experience in producing live talent shows, facts and figures are presented to show why film and film techniques are better suited than live talent for approximately 60 or 70 per cent of the majority of television studio programs.*

Also discussed is the investment in studio equipment and manpower necessary to create and transmit, for one time only, a relatively few hours of live talent programs per day.

Twenty-five years ago—way back in 1921—radio broadcasting was a new, unproved industry. Prominent figures in the advertising, manufacturing, motion picture, and newspaper worlds were expressing opinions both pro and con. Some wanted radio broadcasting and wanted it badly; some did not want it at all. Some said it would be a great advertising medium; others said "bosh." There were some who claimed it a wonderful amusement and educational medium. Others said "Ridiculous! Who will pay for it?" Some of these men knew what they were talking about; some did not. Executives of some of the biggest companies issued statements which I am sure they would like, in some cases, to have expunged from the record. For example, here is a quotation from the *Radio Daily* dated February 3, 1924:

> "A surprising development in radio has arisen with the formation of a committee of New York business men to solicit funds from the radio audience of a local station. Money collected will be used to hire entertainers. . . . Word has been received that experiments in radio advertising are to be tried out, to which the descriptive phrase 'the fourth dimension of advertising' has been applied."

Here is another dated August 15, 1924:

> "Martin P. Rice, speaking for General Electric, believes that broadcasting will eventually be supported by voluntary contributions or by licensing of individual radio sets."

---

* Presented May 15, 1945, at the Technical Conference in Hollywood.

** Executive Vice-President, RKO Television Corporation, New York.

And here is another dated December 20, 1924:

"It is generally supposed that Westinghouse has more than a scientific reason for developing the new art of shortwave broadcasting. By its means, they no doubt hope to be able to establish chain broadcasting *despite A. T. & T. ban on leased wires.*" (Italics by author.)

Again, under the date of March 13, 1925:

"'The radio is not a legitimate medium for advertising; its purpose is to furnish people with good music and other forms of entertainment,' said Dr. Lee DeForest when he addressed dinner guests of the Harvard Business School Club the other evening."

Herbert Hoover said at the first radio conference in 1922:

"It is inconceivable that we should allow so great a possibility for service, for news, for entertainment, for education, and for vital commercial purposes to be drowned in advertising chatter . . ."

He made another try at the conference 2 years later in 1924 when he said:

"I believe the quickest way to kill broadcasting would be to use it for direct advertising."

And finally, being very persistent, he said in 1925:

"Advertising in the intrusive sense will dull the interest of the listener, and will thus defeat the industry. Furthermore, it can bring disaster to the very purpose of advertising if it creates resentment to the advertiser."

Television moves into the scene and we hear the "same record being played." Some want it badly; some do not want it at all. Some say it would be a great advertising medium; others say "bosh!" Some claim it would make a good amusement and educational medium, and others say "Ridiculous—who will pay for it?"

I represent a motion picture company. I do not intend to speak for other motion picture companies, but RKO has the vision to look ahead. We shall, of course, be interested in theater television—*that* is television with a box office. We would naturally be interested in that. We are interested in home television because some day, according to our own beliefs and the expressions of others whom we believe qualified to predict, there may be as many as 30 million television screens in the homes of this country and perhaps another 30 million screens scattered throughout the rest of the world. If as many as 3 people look at each of these screens at one time, there is a potential audience of 180 million.

Why should not we be interested? Why should not the advertiser be interested in that many screens? I am going to get right into the subject of my discussion by making this assumption: I believe television will become one of the greatest mediums for advertising, sales promotion, and entertainment we have ever known. I am going to try and tell you why I think the motion picture film is the best medium to convey these messages.

At the first Annual Conference of the Television Broadcasters Association, held in New York in December, 1944, a top executive of a large broadcasting network made the statement that television receivers would be expensive in the early days of distribution, $300 to $350 each and, to quote him exactly, "Television is not colossal. Television is here and the public is ready to receive it when the producers deliver it. My own concept is that no city can support one television station unless it has a population of at least 500,000 people." There are in the United States today only 9 cities having a population of a half million or over. At the present time there are on file with the Federal Communications Commission applications from hard-headed businessmen for nearly 120 television stations in about 45 different cities from 45,000 population up.

I would like to quote from testimony given before the FCC frequency allocation hearings in October, 1944, by an executive of one of the largest networks, NBC in fact. This gentleman is charged with the duty of formulating plans for the development and expansion of television networks. "During the course of this hearing, the Commission has indicated its interest in how far the service of television can be made available to those living in nonmetropolitan areas. My studies and discussions with affiliates have convinced me that television broadcasting is practical in a town of 25,000 with normal density of population in the surrounding rural areas." Now someone is wrong!

I quote further from the first executive's statements: "I further believe that not more than 10 per cent of the people in the foreseeable future are going to be eligible to receive television receivers either from the viewpoint of income or the ability to get satisfactory reception from one or more television stations in their community." This utterly amazes me. I am sure all of us can remember how we paid what now appears to be exorbitant prices for crude radio sets with their large collection of external batteries, chargers, loudspeakers, *etc.* I do not know of a single manufacturer who does not feel confident that he will put out a good, workable television receiver for as low as $175–$200, and perhaps even lower. I cannot but feel that this gentleman's views are based not on facts as much as they are based on desires and personal preferences. The same speaker also said that films, for a while, may supply part of the programming for television and for a limited time the public would tolerate films. "Tolerate" is his word. May I humbly call your attention to the fact that over 80 million people a week go to the movies and *pay* for it? The annual box-office "take" in 1943 was $1,800,000,000 and it was higher in 1944. I think, therefore, that if we *give* people good entertainment on film for nothing, they would not only "tolerate" it but would welcome it in comparison with some of the live talent shows it has been my misfortune to see.

Here is another statement—this time, by a very good friend of mine, Gilbert Seldes, Director of Television Programs, Columbia Broadcasting System. In an article written for the *New York Times* dated December 24, 1944, he refers to a little live talent dramatic sketch he put on and of some of the problems incidental thereto. "We found that all our estimates for rehearsal time with televisors were grossly low. Much can be done in advance; but you have to go under the lights and see the results in your monitors before you know what you've got. We used, actually, some 8 different sets in 30 min; they ranged from a blank wall—a neutral shot against which the narrator began and ended his story—to a kitchen in a cabin, complete with stove. For the most part we managed to keep the action flowing steadily; when changes were too complex to be made in a few seconds, we added 10 or 15 sec by throwing on the screen a symbolic image, the outside of the cabin, or a bus sign, or a recruiting poster. We felt acutely the need for speedy movement. We recorded certain long solo speeches. Among other advantages, the records allowed us intervals of a minute or two for making set changes."

It seems Mr. Seldes had to use every device he knew of to pad and slow down the performance, which is deadly in showmanship. We in the movies think of every device we possibly can use to speed up action, not slow it down. Had Mr. Seldes been working with films, he would have had no problems that a pair of scissors could not cure.

He now speaks in this same article about new techniques that television brings. "The moments when you hit this special quality are the biggest kick in television right now, and your audience gets it, too. The other day we got it in another experiment; we took a series of drawings of a WAC giving jiu-jitsu to an apache dancer." (Now *there* is a program that must have been thrilling! That is going to *make* television!) Mr. Seldes said, "We got 2 dancers to re-enact the strip, and as they reached certain high spots, we dissolved from them to the appropriate section of the original strip of drawings." (Now, get this sage observation—) "It was not an esthetic discovery; it was only something that could not be done anywhere except in television. It had a unique quality. And our audience responded to it immediately." I frankly do not know what Seldes means when he then says, speaking of this latter invention, "It can only be done in television." It was done 30 years ago, in the movies.

It was because of observations such as these and others that I opened my address in the Theater Panel of the Conference of the Television Broadcasters Association with the following statement, and I wish to reiterate it: "There has been some unfavorable comment concerning the use of film in television programming. Why? Sometimes, because of prejudices, desires, wishful thinking, unfamiliarity with the possibilities of the medium, inability to use it correctly, or just plain ignorance."

The use of the motion picture for the presentation of a television program immediately frees the writer, director, and producer from the shackles of the live stage. A television program using live talent naturally faces many of the same restrictions that limit a stage production. All action at any given time is on a single set, or a group of simulated sets, and because the action is continuous, the players are held to a single costume. Offstage action can only be referred to, and not shown, unless an intermission is declared for a shift of scene and a change of costumes. But with television there can be no between-the-acts intermission. An intermission on a television program would cause the audience to dial promptly to another station. True, a system of revolving stage sets, multiple cameras, and quick costume changes might be employed, but the technical complications would be enormous. At best, it would permit only a very few locale changes, but would continue to impose a multitude of restrictions on both writer and producer. There can be no reverse shots for, naturally, there is no stopping the show and moving cameras and gear to a new setup. Live talent proponents are talking of as many as 6 cameras on one set at one time. I am wondering how they propose lighting such a set. How do they propose to light the actors so they even approach the present motion picture lighting standards? I hesitate to even estimate the rehearsal time necessary for such an elaborate set-up.

All of these handicaps and restrictions, however, are immediately removed when it is a film program. As for locale changes, the problem is most simple. Should the script call for an authentic street scene in Calcutta or Miami, a blizzard in Alaska, or a storm at sea, it would be available from the extensive film libraries maintained by RKO in Hollywood or Pathe News in New York. The players called for in the script would perform against the background of such a scene in such a natural manner that to the television viewer it would all appear to be taken on location. When film is used, rather than live talent, this and hundreds of other proved motion picture devices can be employed to give the television program producer practically limitless freedom of action.

One of the ever-present dangers in live talent production is the "fluff" or "blow up." This will ruin any dramatic performance on television. A stage wait—just a second—can snap the emotional thread of any show. A television director must cut his show as it goes on the air—push a wrong button—fade in the wrong scene—disaster. There has never been any substitute for pre-editing. Certainly no sane advertiser would trust to any demonstration of his product before millions of pairs of eyes if there was the barest possibility of a slip. I actually saw a piece of nonbreakable glass, bearing a nationally known trademark, break into a million pieces when it was subjected to a hammer test. An incident like that could laugh a 10-million dollar company out of business over night.

Another great plus in the use of film is the availability of the animated drawing, either separately or in combination with regular film presentations. The possibilities of animation for the advertiser in diagrammatically demonstrating his product also opens up a fascinating new world for commercials.

I believe that the most suitable type of television programs, as they are evolved through experience, will be far different in character from the feature motion pictures created in Hollywood for theater exhibition. No hour and a half and 2-hr shows. Fifteen- and 30-min shows, even shorter. In the evolving of such programs, however, motion picture techniques will play a greater part than existing radio techniques and the use of film will be infinitely more important in television broadcasting than the electrical transcription disk is today in radio.

Another objection to programs on film has been that they do not have the sense of "immediacy" that live talent has. I do not think that is true except, of course, in the case of sporting events, spot news, fires, floods, *etc.* There is no one who appreciates the live performance provided by the legitimate stage any more than I do. There is something about sitting in a theater watching a good play performed by capable actors and actresses that has no substitute; but if you were to put television cameras in that theater and watch those actors and actresses from a distance, it is then nothing more than a motion picture, and because of its cramped locale and immobile cameras, a bad one. It loses the personal magnetism, the feeling of live flesh and blood—that thing known as "theater."

Here is another reason why I cannot agree to the theory of immediacy. Every day as I come to my office, which is in the same building as the Radio City Music Hall, I see literally hundreds of people on line in all kinds of weather patiently waiting to go inside and see a picture which they know was completed several months ago. The people know the middle scenes were shot first and the first scenes shot last. They know each scene was taken and retaken. Yet they line up to get in. Why? It is only a 2-dimensional moving shadow, but the actors and actresses will make them laugh or cry, or forget themselves for a few fleeting hours. It is *showmanship!*

Television, like motion pictures, is showmanship by remote control. It has been said many times: The high cost of programs on film is an impossible obstacle. I do not believe that programs, in order to be entertaining and good, necessarily have to be expensive beyond reason. Some radio programs today cost from $10,000 to $25,000 for a 30-min period. That is a range of from $300 to $600 a min. We know we can supply film shows for that much and less and, of course, more.

I am worried about the high cost of live talent programs—the vast amount of equipment and personnel needed to put a comparatively few hours of live talent programs on the air. This is the knotty little economic problem of television which keeps occupying the attention of prospective station operators, especially the so-called originating stations for networks. There are a lot of people who say that television will operate only between 4 and 6 hr a day. Others point knowingly to a 24-hr-around-the-clock schedule. Let us take for our example a day which calls for 8 hr of live talent studio programs. What would be required to put on 8 hr of programs a day if they were all *live* talent programs?

Thomas H. Hutchinson, Director of Production of RKO Television

Corporation, has prepared a chart, shown as Fig. 1, and supporting explanation:

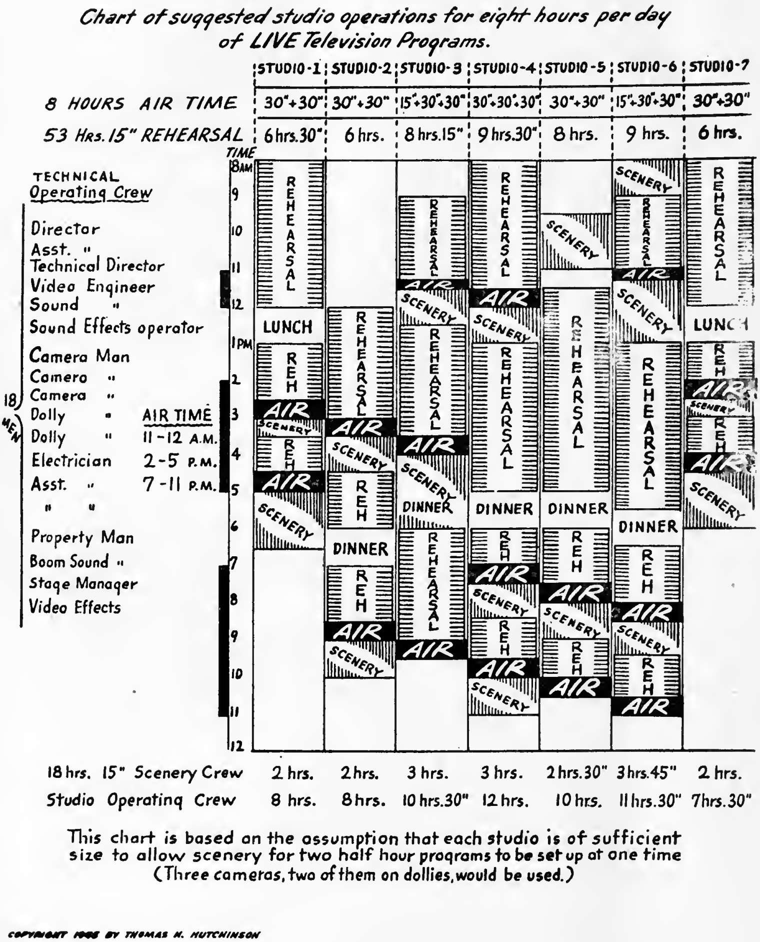


FIG. 1.

"The chart of studio operations for 8 hr a day is based on several very important assumptions. First, that each studio is of sufficient size to allow for the placing of all the scenery to be used in 2 half-hour television programs. Secondly, it is assumed that each 30-min unit can be rehearsed in approximately 3 hr, before the cameras. No consideration has been given for previous rehearsals. In studio *1* there are shown $5^1/_2$ consecutive hr of rehearsal before the first program goes on the air.

"It is presupposed in this chart that the second program will have been rehearsed during part of this $5^1/_2$-hr rehearsal period. The program to be broadcast between 4:30 and 5:00 might rehearse from 8:00 to 10:00 in the morning and from 3:30 to 4:30 in the afternoon. The first program from this studio scheduled from 2:30 to 3:00 would rehearse from 10:00 to 12:00 and from 1:00 to 2:30. This would allow 3 hr rehearsal for the program broadcast from 4:30 to 5:00, and $3^1/_2$ hr for the program broadcast between 2:30 and 3:00.

"No attempt has been made to indicate the exact number of studio operating crews necessary in a day's cycle. In studio *4*, for example, there are shown three 30-min programs. If the procedure suggested in studio *1* were applied here, one operating crew would report at 8 A.M. and rehearse until 11:30. The program would then be broadcast from 11:30 to 12:00. At 1 o'clock a new operating crew would report and would rehearse and broadcast the 2 programs scheduled from 7:00 to 7:30, and from 9:30 to 10:00. No attempt has been made to fill in the extra day for the first operating crew. Under this procedure they have only worked a 4-hr day, but at the same time, unless there was an additional studio available, there is no way with only 7 studios to utilize their services in active operation for the other 4 hr.

"It will always be necessary to balance operating man-hours against studio facilities. It will always be virtually impossible to get 100 per cent efficiency out of any operating crew. Time for changing scenery during rehearsal periods has been arbitrarily allotted. This has been done in an attempt to increase the efficiency of the scenery crew. It will readily be seen that if the scenery time scheduled on the chart during an operational day is eliminated and all scenery is changed after the studio is through for the day, it will take a scenery changing crew for practically every studio, whereas, if it is handled as suggested in the chart, the number of crews necessary may be considerably reduced.

"This chart is also based on the assumption that the programs to be broadcast can be rehearsed satisfactorily on a 6-to-1 ratio. All programs will not take this long and proper planning should make this schedule workable, but programs may have to be changed to conform to the rehearsal time available. No reference has been made in this chart to the number of men involved in the scenery crew. That will depend entirely on the amount of scenery used for each program. No reference has been made as to the amount of scenery that will be required. This will depend entirely on the type of programs produced and the production standards set by the station. It seems only reasonable to assume that the 17 program units indicated on the chart would require at least one set each, and some programs might run as high as 5 or 6 sets per unit. All of these sets must be designed, built, and painted and no attempt has been made on this chart to estimate the amount of time or the number of men required to do this.

"If the schedule were to be changed so that one consecutive hour of program was presented rather than two 30-min programs, it might very well be that much more rehearsal time would be necessary than is indicated here.

"Roughly, it can readily be seen that each hour of program per day is going to require a studio, an operating crew of 18 men, a crew to change scenery, and a crew to build and paint it, but the chart does show how one studio might be eliminated in a normal day's operation if the programs were planned and produced as indicated. The chart only covers production for one day. On a 7-day operating week it is obvious that it would be necessary to use swing crews for the extra 2 days as the same crews should produce the same programs each week."

How very simple it is going to be when programs are provided on film. A large motion picture company can arrange with the advertising agency for whom it functions to supply identical prints of a program to any number of television stations throughout the country or, for that matter, the world. It would do this precisely as it supplies its regular motion picture film, on a "day and date" basis. This would be done through its nation-wide network of film exchanges. No excitement, no worry, no scurry—just as simple as loading a home movie.

Public relations via television opens up a vast new field of opportunity. Today, more than ever before, it has become necessary for big business to justify its existence. Television on film will offer a most unique and effective method of spreading the story of the large corporation to the public. In a most entertaining manner it will be possible to portray what a big company does for its employees—group insurance, social service, hospitalization, home economics, company stores, extension courses, bonus system, job insurance, retirement funds. What better way could there be to present this story to the peoples of the world than via the motion picture films?

The screens of the majority of motion picture theaters in this and many other countries have been closed to the advertising or business propaganda film, and rightfully so. People do not wish to buy propaganda or advertising when they go to the theater. Television will open the home screens of the world to the advertiser. Here again the efficacy of the television program on film becomes apparent. You cannot drag television cameras all through a big plant and put on a carefully planned show. Also the finest live talent program produced in America means nothing in a country where English is not spoken or understood. The cost of the program or series of programs must be borne by the one-shot performance. Suppose it were to cost 10 times as much to put it on film? By the simple expedient of "lip dubbing," we can translate the program into any and every language and send prints of such programs to all countries just as we now send foreign versions of our motion pictures. This enables our giant corporations whose scope is world wide to reach via television not just millions in this country but, eventually, billions of people.

The cost of installation and operation of a television station will be considerably higher than that of a radio station. However, a message or an advertisement can definitely be put across in much less time than it takes via radio. That will offset the higher operating costs. Radio programs are sold and produced in 15-min periods. Why not 10-min periods? There would be a $33^1/_3$ per cent saving right there. The show would probably be tighter and faster moving, too.

I hope it will always be remembered that television is primarily a visual art. I hope that it will not be burdened with the top heavy verbosity we hear every day over our radios. I do not think that the American public is quite so dense or impervious to suggestions as some of the radio commercials we hear would lead us to believe. Suppose any one of you were this evening to stroll through the lobby of this hotel. There you spied a very attractive young lady. You caught her eye and she caught yours. She looked right at you, smiled, and perhaps gave you a knowing little wink. I wonder if there is anyone in this room who would not know what to do in such a case—or what not to do! I cannot conceive of having a hearty-voiced announcer from somewhere give you a 2-min sales talk!

In almost every motion picture you see, there are several complete situations—some of them involved, which are conveyed to the beholder with complete clarity in a twinkling of an eye without a spoken word. One of these methods is known as the "doubletake." You have all seen it used. A quick look, and then another look. A gesture, a movement of the hand, an expression of the face, a sly wink. Each of these devices can convey more immediate understanding than a hundred words. Barry Fitzgerald feels that in contemporary pictures there is too much dialogue. The finest acting, he says, is still pantomine. A look, a twist of the neck, or the way a person walks, can tell more than whole pages of dialogue. In *Going My Way*, for instance, the glance of disapproval he gave his curate, Bing Crosby, when he discovered him wearing a sweater with "St. Louis Browns" spelled on it, or his silent shame when he learns that the turkey on which he is feasting has been stolen, tells more in less time than even the brightest dialogue. *Good* television will definitely shorten the amount of airtime needed to put over a message. Let us hope and pray we can so convince the advertising agencies.

During the past few months many inquiries from prospective advertisers and prospective telecasting station operators have been made which indicate that while they have great faith in the ultimate future of television, they are rather puzzled as to how they can program their stations. Sooner or later the discussion veers to the use of programs on film, film transcriptions, or, as RKO refers to them, *Telereels*. The average radio station operator, the word "average" here meaning one located at a distance from one of the major metropolitan districts, is now dependent upon programs that reach him from talent centers. Ordinary radio broadcasting has shown us that local talent cannot supply more than a fraction of the needed program material.

It is quite evident that telecasting stations will be in operation considerably sooner than network programs will become available and it is here that the film transcription or *Telereel* will prove to be the backbone of the programming system.

RKO is going to make syndicated programs available as soon as station construction starts. Even after national or large regional networks are established, the *Telereel* will remain an important, if not the most important, factor for all programs with the exception, of course, of sporting events and news events which are always hot, flash news.

No single individual advertiser, no single advertising agency, nor any group of advertising agencies could possibly operate such enormous facilities as RKO and its subsidiary, Pathe News, Inc., now offer the potential television users of this country. These facilities are now available to both reputable advertisers and recognized advertising agencies through RKO Television Corporation.

In the post-war period when television will flourish, the advertising dollar will be scrutinized more carefully than it is today. National advertisers will not be so ready to buy a 15-min or half-hour spot on a network between the East and West Coasts and perhaps be in competition with a top rating program carried by another network, or face a 3-hr time differential. Advertising managers and market analysts will lean heavily on the spot type of telecasting. They will pick the markets in the order of their desirability, concentrate their appropriations on selected territories, and make it a point to cover them at the best possible hours. Perhaps they might even give a repeat show. Why are good radio programs today not repeated? We can only listen to one program at a time. How often has a friend of yours said to you one morning, "Did you hear so-and-so on the radio last night? He was marvelous." You say, "No, I didn't. I was listening to another program, or, I was out last night. I'd like a chance to hear that program you speak of—it sounds wonderful." I do not think advertisers today get nearly the circulation from their radio programs they should because of this one-shot feature. A Hooper rating of twenty says to me, "What happened to the other eighty?"

I believe it will be perfectly possible and feasible to release a program over a "first-run" group of stations, and then rerelease it in the same locality at a later time to a "second-run" group, and finally a "subsequent-run" group. Any given locality can be thoroughly and completely covered. The Hooper rating will go well up and the "cost per thousand" listeners go way down. The television industry can learn a lot from the motion picture industry.

Obvious, indeed, would be the great saving in land line or radio relay charges by the use of *Telereels*, and obvious, too, is how much greater a percentage of its rate card a local station operator would be able to retain.

I do not wish to create the impression that it is my belief that there will not be any live programs. This is farthest from my mind. There are certain types of programs that will always be done best in the flesh, as it were, interviews of prominent people, style and fashion displays, all kinds of sporting events, outdoor pageants, in fact, any event whose main attraction is uncertainty of the outcome, such as a football game. But, as you have undoubtedly gathered from my remarks, I am very "bullish" regarding the eventual triumph of film over live talent. *It will be the backbone of television programming.*

This is my case, then, for the employment of the motion picture to carry the public relations message, advertising, education, and entertainment via television. I recommend the employment of the same medium that has so successfully spread American culture and American ideas over the face of the entire globe.

POWER RECTIFIERS FOR STUDIO LIGHTING*

L. A. UMANSKY**

Summary.—*Mercury arc rectifiers are now widely used in the industry for converting a-c to d-c power. Since d-c power is required for operation of arc lights in motion picture studios, it is of interest to analyze whether the use of rectifiers for this purpose has advantages over other power conversion means. This paper points out the relative merits of rectifiers and motor generators.*

INTRODUCTION

Motion picture studios, employing a great number of high-intensity arc lights, require a large amount of d-c power. In some cases as many as 8, 10, or more motor-generator sets, up to 500 kw capacity each, are employed in a single substation supplying direct current to several studios on the same location.

The d-c power system is usually arranged as a 3-wire, 125–250-v circuit, in order to save on distribution copper, with arc lights connected between the neutral and either polarity.

Mercury arc rectifiers have firmly established themselves in many industries as the preferred means of a-c to d-c power conversion. It will not be amiss to state on this occasion that during the peak year of war production about 10 per cent of all electrical energy produced in the United States has passed through rectifiers and has been utilized as direct current. Close to 3,500,000 kw of rectifiers are installed in this country alone. While the bulk of this capacity is provided for the electrochemical plants, there is hardly any industry where the rectifiers have not proved themselves as a reliable, and often preferred, conversion means.

It is, therefore, pertinent to review the possibilities of the use of rectifiers for the application in which we are interested, *i. e.*, for supplying d-c power to the studio lights.

---

* Presented May 18, 1945, at the Technical Conference in Hollywood.

** Industrial Engineering Divisions, General Electric Company, Schenectady, N. Y.

PRESENT RECTIFIER APPLICATIONS

To provide the proper background for our discussion, a bird's-eye review of many typical rectifier applications is in order.

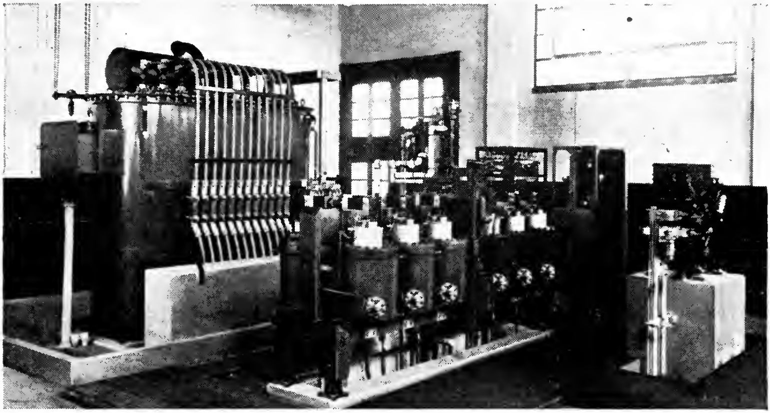


FIG. 1. A 3000-kw, 650-v rectifier supplying power to New York City subways.

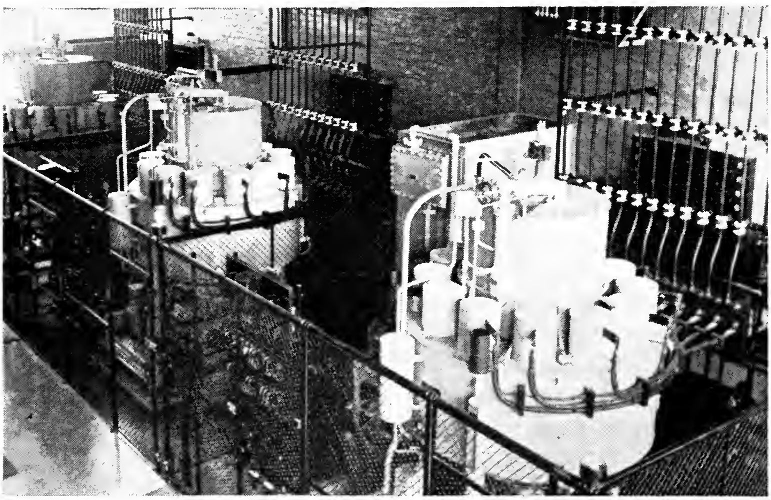


FIG. 2. 3000-kw, 3000-v rectifiers supplying power to DL&WRR.

The first rectifiers in this country were used for electric railways and street cars. In the first place, the rectifier, being a static device with practically no moving parts, permitted the design and building of unattended a-c to d-c substations—quite an item in operating expense of a railroad. Secondly, the high d-c voltage—600 v and higher—used for this purpose, particularly favored the rectifier since its efficiency goes up with d-c voltage, and its first cost goes down.

For instance, Fig. 1 illustrates a 3000-kw, 650-v rectifier installed in New York City subways. A total of 261,000 kw of rectifiers were installed on this system since 1930. Fig. 2 shows a group of four 3000-kw, 3000-v rectifiers supplying power to the suburban line of the DL & W Railroad.

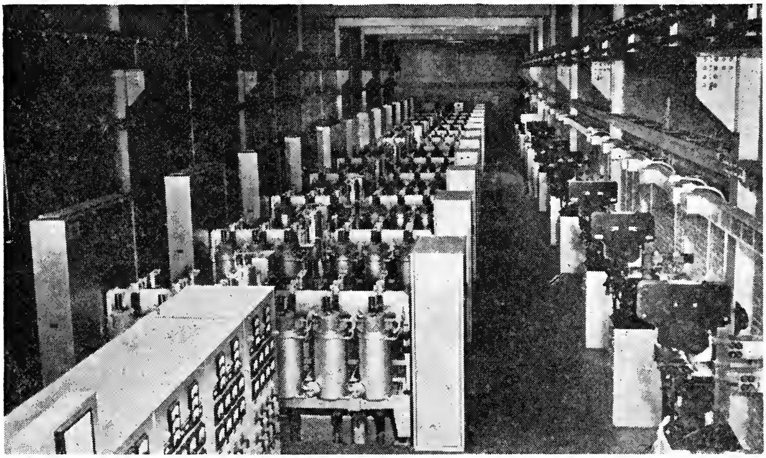


FIG. 3. Twelve rectifiers supplying a total of 60,000 amp at 650 v to an aluminum electrolytic pot line.

Since just before the war, the use of rectifiers in the electrochemical industry began to grow by leaps and bounds. In the production of many chemicals, and particularly in the production of aluminum and magnesium, an electrolytic line is part of the process, and a very important part at that. Many so-called "pot-lines" for these light metals require 50–60,000 amp each of direct current at voltages of about 650 v, more or less. Fig. 3 gives a general view of such an installation involving twelve 5000-amp, 650-v rectifiers in an aluminum plant. Over 2,500,000 kw of rectifiers have been installed within the last few years in the chemical industry alone, to the exclusion of any new rotating machines as a-c to d-c converting means. There are a good many reasons for this preference.

Efficiency is higher (see Fig. 4) while the cost of power is an important item in the total production cost; for instance, even at 2 mils per kwh, a pound of aluminum will require 2 cents worth of electric power as compared with the selling price of 15 cents per lb. Installation costs with rectifiers are lower. Maintenance expenses are reduced. Fewer, if any, substation attendants are needed. These and other factors have decided the issue in favor of rectifiers in that industry as in many others.

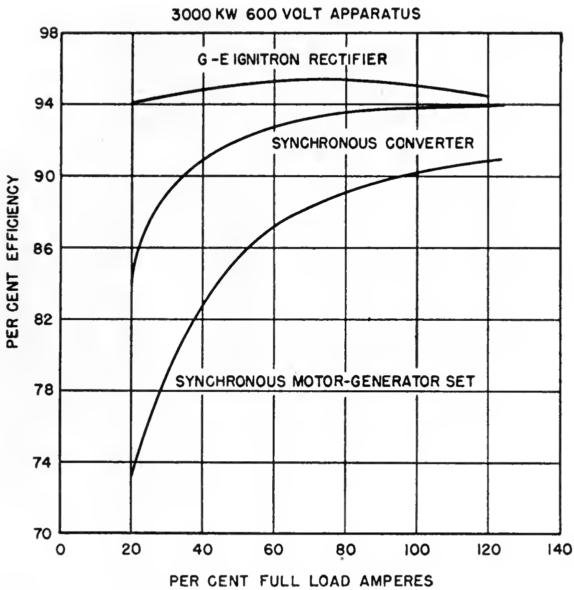


FIG. 4. Efficiency of a 3000-kw, 600-v rectifier as compared with rotating conversion equipment.

Fig. 5 shows a 1500-kw, 250-v rectifier used in a steel mill to supply general purpose power. Here, again, the substation can be made unattended. While the full load efficiency of the rectifier even at this voltage is somewhat higher than that of a motor generator, the improvement of the part-load efficiency is particularly noteworthy (see Fig. 6); in this type of service the load is intermittent, and the overall load factor is not always very high. Therefore, the all-day efficiency of the rectifier substantially is higher than with a synchronous motor-generator set.

Many other diversified industries took to rectifiers as well. For capacities up to 500 kw, 250 v, which are usually required in many such cases, an enclosed design (Fig. 7) has proved to be quite popular. Incoming line a-c switchgear controls the primary of the rectifier transformer to which it is "throat-connected." The transformer is likewise connected to the rectifier cubicle and d-c switchgear. Fig. 8 shows the inside of the rectifier; it includes several steel-jacketed, water-cooled ignitron tubes. More will be said of these tubes later on.

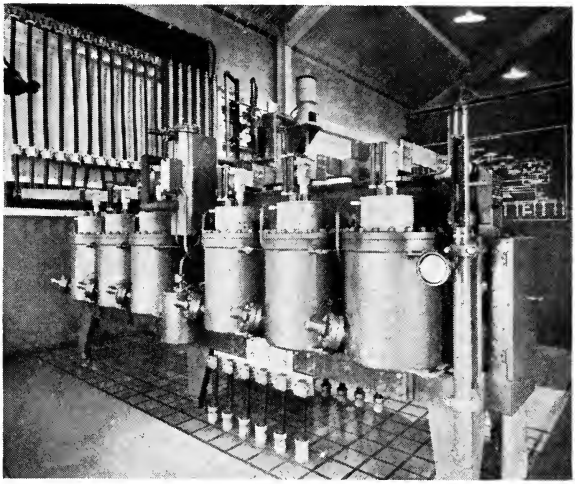


FIG. 5. A 1500-kw, 250-v rectifier used in a steel mill.

Rectifiers are also used extensively underground in mines. In this case they are usually made portable, as shown on Fig. 9. The first car carries the primary a-c switchgear, the second car, the transformer, and the third car, the rectifier tubes, d-c switchgear and accessories. As the mine is being worked farther and farther, the rectifier is also moved to be nearer the center of the load.

This brief review gives us a general picture of the place taken by the rectifiers in industry. Our next step is to have a closer look as to how the rectifiers are built, and what makes them work.

RECTIFIER TUBES

The heart of each rectifier is, of course, the electronic tubes which actually convert the alternating current into direct current.

High vacuum or "hard" tubes are not ordinarily used for power rectifier work for obtaining commercially usable d-c voltages and currents. Gas filled, hot cathode tubes, such as phanotrons and thyratrons are employed for moderate capacity up to about 25 amp per tube. For larger capacities, such as we are interested in, the mercury pool tubes are almost universally used.

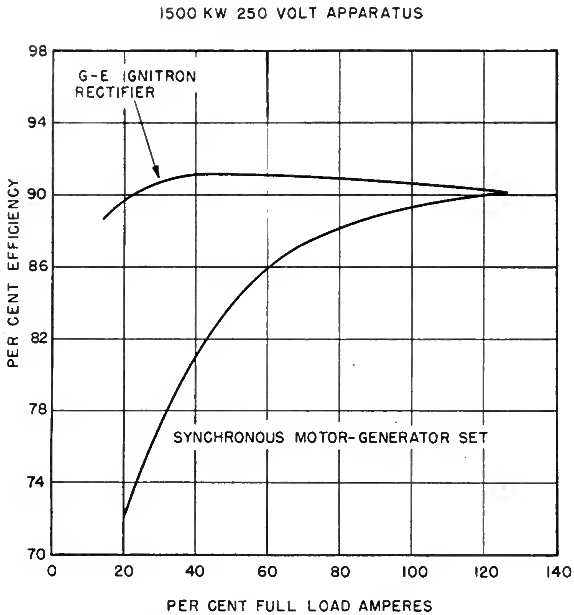


FIG. 6. Efficiency of a 1500-kw, 250-v rectifier as compared with a motor generator.

The most popular of these tubes is the ignitron, shown in Fig. 10. It is a metal envelope, water-cooled tube, with a graphite anode, and a pool of mercury acting as cathode. Using mercury for this purpose gives us several advantages.

The electrons of the mercury atoms are loosely held by the positive charge; a lower temperature and lower voltage are required to emit electrons than would be the case for other metals. Mercury vaporized by the cathode also offers a means for production of electrons in its own vapor. The recombination of electrons and ions constantly occurs at the same rate of ionization. These mercury atoms recondense and return to the cathode pool. Therefore this pool is continually and automatically maintained. "The mercury does not wear out."

An ignitron tube is "started" for each cycle, by creating a new "cathode spot" for each cycle. This is done by means of an igniter whose point, made of boron carbide, is dipped in the mercury pool. At a certain instant of each cycle a voltage is applied to the igniter from a special "peaking" transformer, and current flows through the igniter to the mercury. Since the mercury does not wet the boron carbide, the contact resistance is rather high and enough heat is

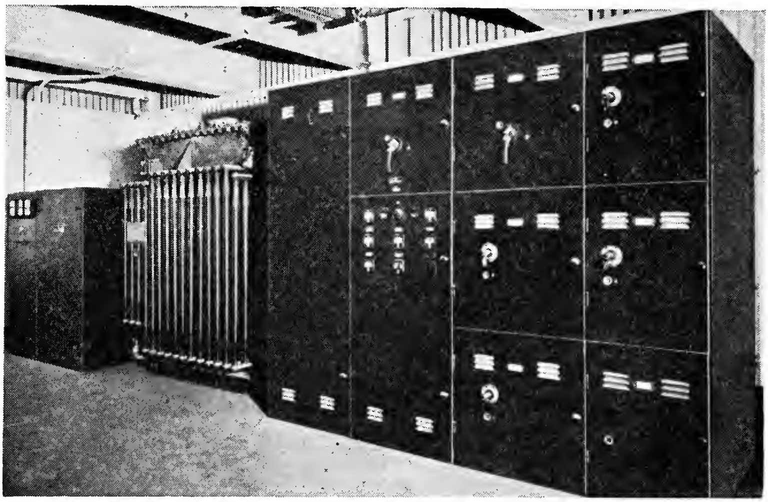


FIG. 7. Front view of a metal enclosed sealed tube rectifier, 300-kw, 250-v, typical of many similar units used in various industries.

generated to produce the cathode spot. The tube becomes conductive and carries current for the rest of the half-cycle. Like any other electronic tube, the ignitron does not conduct any current for the negative half-cycle; *i. e.*, when the anode is negative in respect to the cathode.

Therefore, the igniter point should be energized or "fired" every cycle very much as a cylinder of a gas engine is fired periodically. As will be shown later, the firing circuit is derived from the same source of power as the rectifier itself, *i. e.*, complete synchronism is maintained, just like the timer and distributor of an engine are driven in synchronism with the engine itself. The analogy may be drawn still further: by retarding or advancing the "spark" or ignition, we can modify the output of the rectifier.

Ignitron tubes, as shown in Fig. 10, are sealed off at the factory, and are now available in continuous ratings of 100 amp and 200 amp at d-c voltages of 250 v or less. Their current rating is somewhat reduced at higher d-c voltages, like 600 v. By properly combining these tubes, as we have already seen, rectifiers up to 500 kw, 250 v, or 1000 kw, 600 v can be readily provided.

For larger capacities the so-called pumped ignitron rectifiers are widely employed. Fig. 11 illustrates the cross section of such tube or tank. It consists essentially of the same components as the sealed ignitron. However, each unit is connected through a vacuum tight valve to a manifold which is continuously evacuated by a pump, shown in Fig. 12. This photograph represents an assembly of a 4000-amp rectifier.

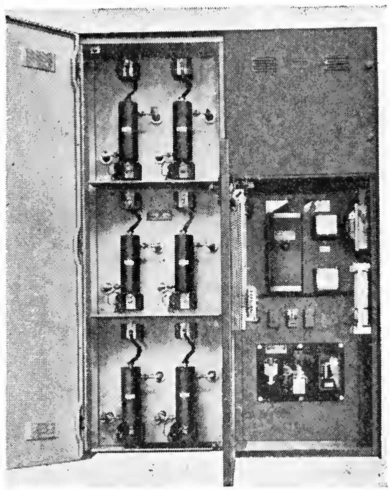


FIG. 8. Inside view of sealed tube rectifier, with compartment doors open.

A complete vacuum pumping system consists of 2 vacuum pumps connected in series, which usually operate continuously when the rectifier is in service. The primary or roughing pump is a motor-driven oil immersed vertical-type compressor similar to units used in refrigerators. It is connected in series through an expansion tank to a mercury condensation pump. In this manner, an almost perfect vacuum of 1.0 micron (1/760,000 part of an atmosphere pressure), or less is maintained.

A pumped rectifier can be dismantled in the field, if desired, and then reassembled, evacuated (or degassed), and put back in service. The igniter point can be readily changed. Thus, a pumped rectifier has no inherent life limit.

There is a definite arc drop voltage in the rectifier tube, even though the advent of the single anode tubes, such as ignitrons, has materially reduced this value.

In the smaller ignitrons of the sealed type this arc drop is from 15 to 19 v. It is somewhat higher in the larger, pumped equipments. The arc drop results in power loss in the tube, which is converted into heat and is removed by cooling water.

The value of the arc drop does not depend on the voltage at which the tubes are operating. It is obvious, therefore, that the rectifier is at its best, as far as its efficiency is concerned, when operating at the maximum rated voltage; better at 600 v than at 250 v; better at 250 v than at 125 v.

RECTIFIER CIRCUITS

With the present interest in "things electronic," the majority of engineers have a general understanding of the performance of simple

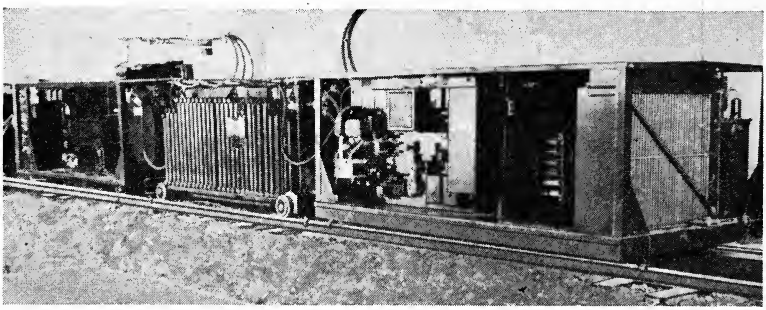


FIG. 9. A portable mining rectifier substation, rated 300 kw, 275 v, mounted on 3 flat cars and designed for low headroom.

electronic circuits. Some of the diagrams are, undoubtedly, familiar to many, but they are included for the sake of completeness and as a ready reference.

For capacities in which we are interested, we are always assuming a 3-phase a-c power supply. Fig. 13(a) gives the simplest arrangement with 3 tubes used for rectification. The anode which, at any given time, is the most positive carries the entire load current. In this case it carries it for 1/3 cycle (120 degrees), after which the current is transferred to the next anode. This transfer is called "commutation."

The resultant d-c voltage is illustrated by the heavy curve, Fig. 13(b). The ratio of average d-c voltage to maximum values is 0.825; the "ripple" is quite pronounced. Therefore, the 3-phase power rectifiers are not as frequently used as those with a larger number of phases.

Fig. 14 shows a 6-phase (diametrical) arrangement of tubes and transformer secondary winding. The ripple is greatly minimized. The ratio of average d-c voltage to maximum values has risen to 0.97. Each tube carries the load current for only 1/6 cycle.

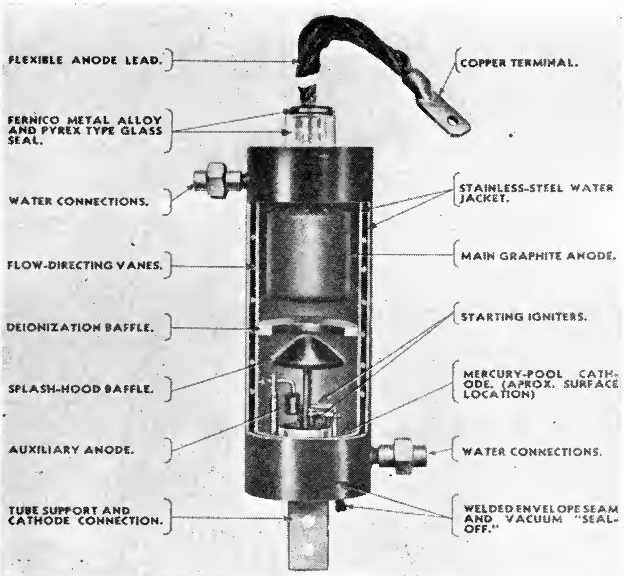


FIG. 10. Cross section of a sealed ignitron tube used for power rectifier work.

The action of transferring current from one anode or phase to another anode is similar to commutation from coil to coil of a d-c machine. This commutation is not instantaneous because the reactance of the several windings involved resists any sudden transfer of current. Therefore, the actual shape of voltage and current is represented by Fig. 14(c), differing from the theoretical shape shown in Fig. 14(b). This means that for a short time during the transfer, current flows simultaneously through 2 anodes.

The "notches" in the voltage curve, Fig. 14(c), show that the average d-c voltage is reduced owing to the commutation factor. This reduction is proportional to reactance of the circuit and to the

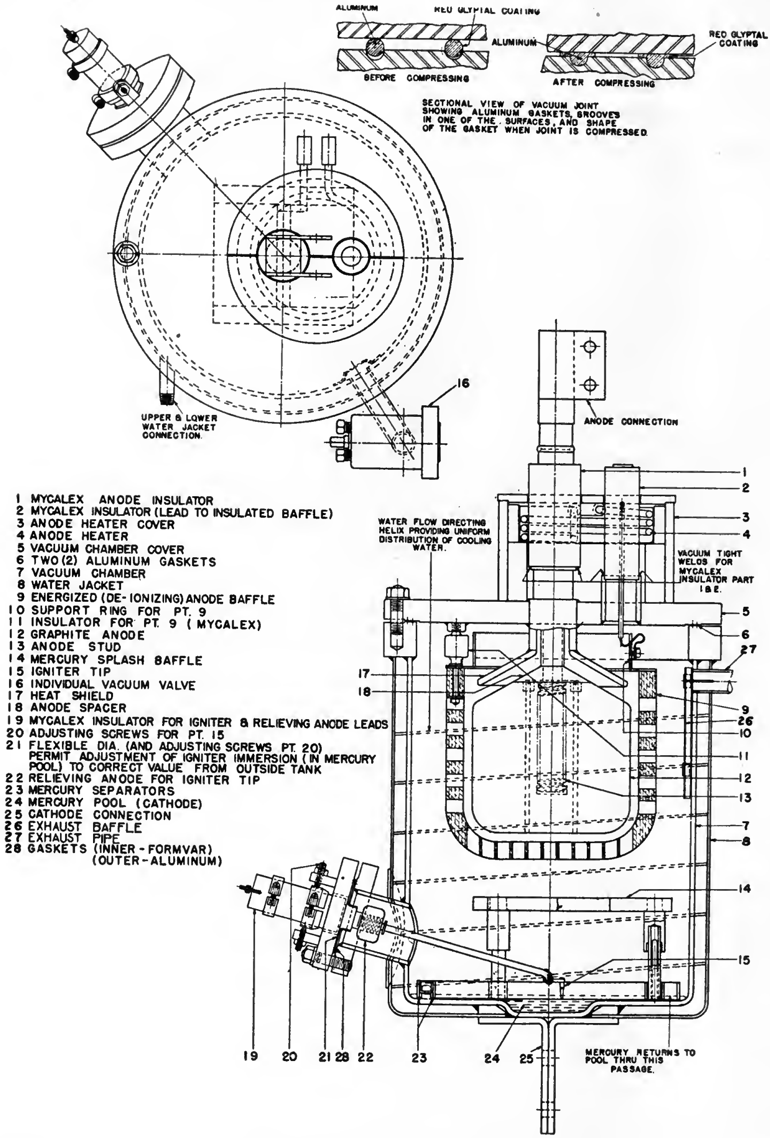


FIG. 11. Cross section of a pumped ignitron tank used for power rectifiers of larger capacity.

value of load. This explains the well-known fact that with a-c voltage being maintained constant, the rectifier d-c voltage will have an inherent regulation of about 6–10 per cent from full load to no load.

Fig. 15 shows the most popular connection of rectifiers used in the great majority of industrial applications; in fact, probably better than 90 per cent of all rectifiers are so arranged. Considering the

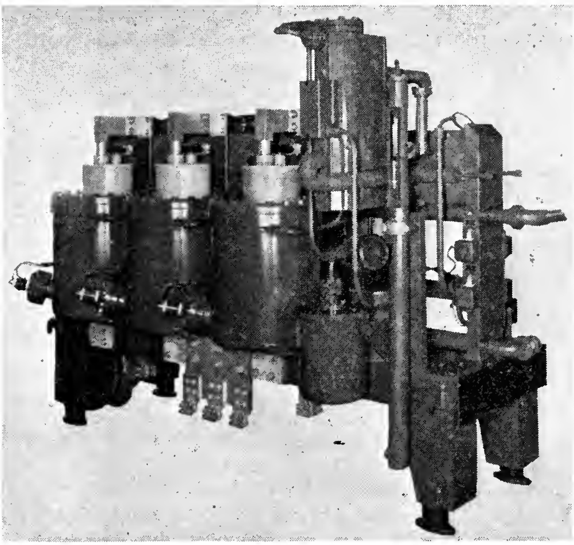


FIG. 12. Shop view of a pump rectifier, 1000 kw, 250 v, showing the vacuum pump.

transformer windings, the arrangement is known as "Delta, 6-phase, double wye."

Comparing Figs. 14 and 15, we note that the wave shape of d-c output voltage from these 2 circuits is the same, the fundamental ripple being 6 times the basic frequency (*i. e.*, 360 cycles with 60-cycle supply). The fundamental difference lies in the action of the interphase transformer, which is the midtap reactor connected between the 2 wyes.

Each 3-phase group or wye operates as a 3-phase rectifier. The wye-points of both groups are interconnected to the so-called "interphase transformer." The latter is usually mounted in the same tank or enclosure as the main transformer, but is wound on a separate core, and is magnetically independent.

Assume now that at some instant the phase (*1*) gives its anode the highest positive potential. The current then flows through the tube No. *1*, the cathode (positive) bus, the load, and returns through the midpoint (*7*) of the interphase and to the neutral of the 3-phase group 1-3-5. As a result, the effective voltage of phase (*1*) is lowered by the amount of the impedance drop across one half of the interphase transformer. The passing of this current induces voltage in the other half of the interphase and, in effect, raises the voltage of phase

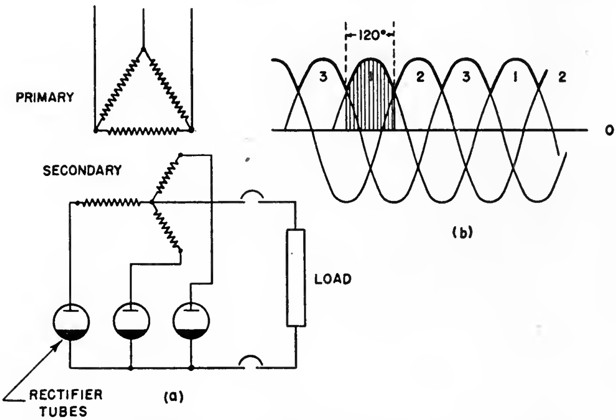


FIG. 13. Three-phase rectifier circuit (*a*) and the wave shape of d-c voltage (*b*). This circuit is used for relatively small power rectifiers.

(*2*) which is next in the line to assume the carrying of the load. The result of decreasing the potential of (*1*) and increasing that of (*2*) is that for an interval of 60 electrical degrees; the anodes (*1*) and (*2*) are at equal positive potential which is then higher than that of any other anode in the circuit. Therefore, for this length of time the 2 anodes share the load; during the next $^1/_6$ cycle the load is carried by anodes (*2*) and (*3*); then by (*3*) and (*4*); and so on.

Thus, the double-wye interphase circuit reduces the peak current to be carried by each tube and by each phase of the transformer winding. The utility factor which indicates how effectively the transformer copper is used is increased, as compared with the diametrical, 6-phase arrangement, Fig. 14. Still, it should be kept in mind that the secondary of even a double-wye, interphase transformer requires about 40 per cent more copper than would the secondary of a standard power transformer of equivalent capacity.

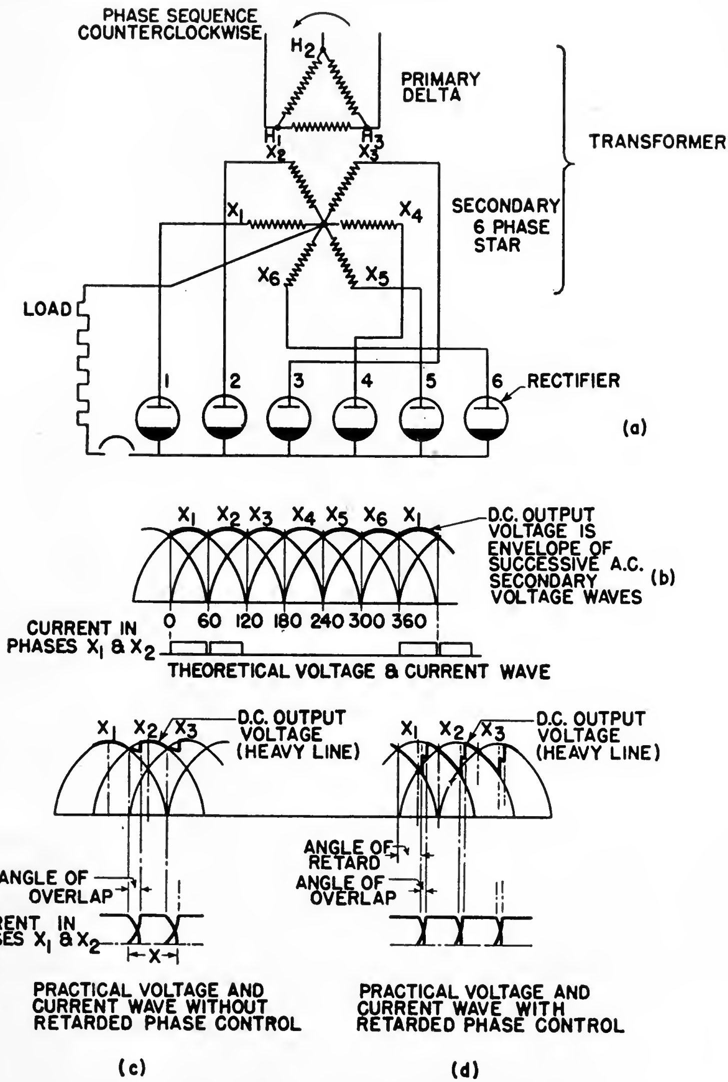


FIG. 14. Six-phase (diametrical) rectifier circuit illustrating the theoretical and practical wave shapes of d-c current and voltage.

Fig. 16 shows another very interesting arrangement of a rectifier circuit. The transformer has a conventional 3-phase wye-connected secondary. With 6 tubes connected as shown we have, in effect, two 3-phase rectifiers: one connected to the positive d-c bus; another to the negative d-c bus. The total effect on the d-c system, as far as the ripple is concerned, is the same as if we had a conventional 6-phase rectifier.

The transformer winding is, however, better utilized since each phase carries current in both directions, and therefore the "utility factor" is greater. Hence it is named "2-way circuit." But, while the transformer duty is lightened, that of the tubes is increased: each

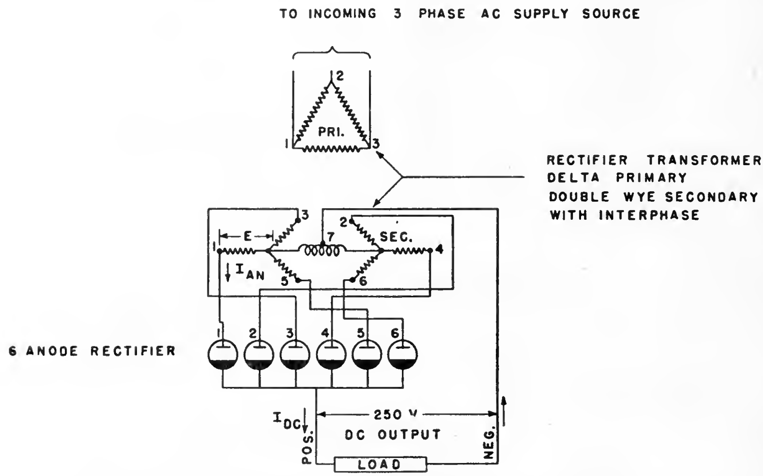


FIG. 15. The most popular power rectifier circuit known as "delta-double wye" with interphase transformer.

tube carries *full* current for $^1/_3$ cycle. Therefore, larger tubes are needed with this arrangement than with that of Fig. 15, everything else remaining constant. The arrangement Fig. 16 lends itself quite readily to a 3-wire system. The neutral of the transformer (see dotted line) can be directly connected to the neutral bus; with 250 v between the positive and the negative buses, we have 125 v between each of these buses and the neutral. Each 125-v half of the system can be operated independently of the other; *i.e.*, one can be fully loaded, with the other carrying no load at all. But, one should remember that each half of the rectifier, as shown on Fig. 8, is only a 3-phase unit, and therefore the d-c ripple appearing on each 125-v system is greater than that between the 250-v buses.

FIRING CIRCUIT AND VOLTAGE CONTROL

We have already mentioned that the ignitron tube must be fired every cycle. The igniters with which each tube is equipped require for the short time of "firing" about 50 amp peak current at about 350 v peak voltage. This should be d-c, or unidirectional current, with the igniter's potential being positive in respect to the mercury pool. Fig. 17 shows one method of accomplishing this, which is by far the most widely used in rectifier work; the diagram refers to a 6-tube equipment, and the power circuit is not shown for the sake of clarity.

An auxiliary control transformer (*ET*) is connected to the same source of power as the main power transformer; this establishes synchronism between the power and the control circuits. Each phase of the excitation circuit excites 2 ignitrons whose anode voltages are 180 degrees apart in phase relation.

The secondary of the transformer (*ET*) energizes 2 networks per phase: (*1*) a network for generating impulses which, when fed to the igniters, causes them to fire; (*2*) an adjustable phase-shifting network which provides a convenient means of phase-shifting the firing point and, consequently, a means of adjusting the d-c voltage output of the rectifier.

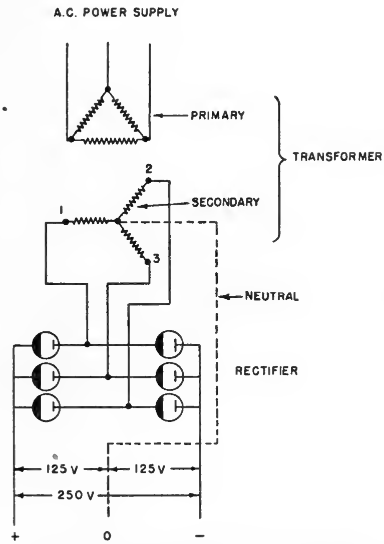


FIG. 16. "Double-way" rectifier circuit, which gives high utilization factor of the transformer, and lends itself readily to the 3-wire d-c service.

The first of these networks consists of a linear reactor (*LL*), saturating reactor (*FL*), and capacitor (*FC*). The linear reactor is designed to give constant reactance up to rated voltage and frequency of the circuit. The saturating reactor is designed to saturate when the capacitor is charged to the maximum voltage, thus allowing this capacitor to discharge through the saturating reactor into the igniter. The effect is shown on the insert of Fig. 17; igniter current curve has a sharp and pronounced peak which "fires" the tube. As quickly as the cathode spot is formed, an auxiliary anode shunts both the dry plate rectifier and the igniter, collecting the arc and thereby relieving both igniter and the dry plate rectifier of considerable duty.

The adjustable phase-shifting network consists of a saturable reactor (*SL*), linear reactor (*CL*), and capacitor (*PC*). The reactance of the reactor (*SL*) is adjusted by means of d-c excitation; the value

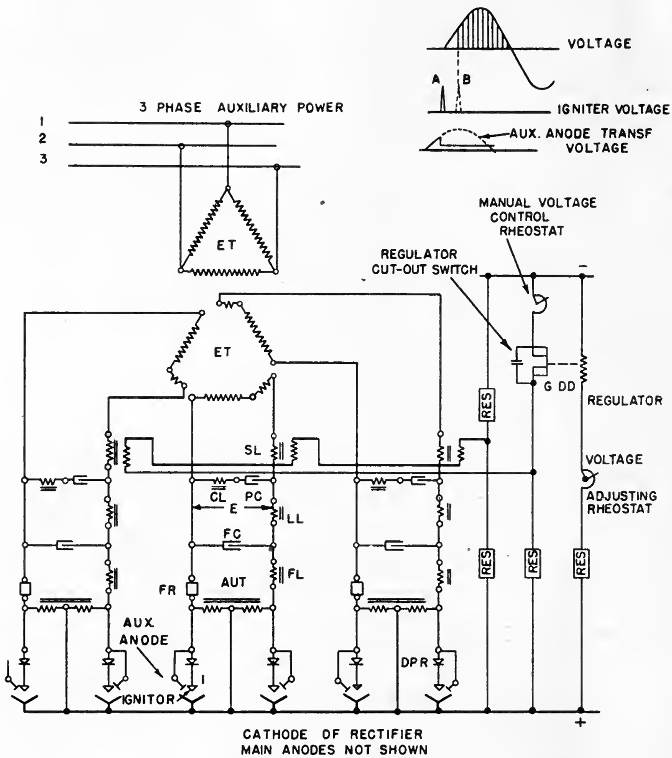


FIG. 17. Excitation circuit for a 6-tube rectifier. The insert shows how the phase retard of firing affects the d-c voltage.

of this excitation shifts therefore the phase angle of voltage (*E*) used for firing; for instance, from point *A* to *B*. This means that the tube will conduct current for only the shaded portion of the cycle. Obviously, the average voltage is reduced when the firing point was moved from *A* to *B*.

Thus, we have a convenient means of adjusting and controlling the output d-c voltage of the rectifier within certain limits, independently of the a-c supply voltage. For instance, by providing a voltage regulator *GDD* (see Fig. 17), the conventional industrial rectifiers keep the d-c voltage constant regardless of wide fluctuations of load and with a-c voltage varying about ± 5 per cent.

Generally speaking, the phase control of firing can be extended to provide 100 per cent voltage control of rectifier, from zero to rated voltage. There are, however, several points which should be noted in this connection:

(*a*) Phase retarding distorts the wave form of d-c output.

(*b*) It lowers the power factor on the a-c side in about the same proportion as the d-c voltage is reduced.

(*c*) The average current carrying capacity of the tubes is somewhat reduced owing to the wave distortion; in other words, if a given rectifier can carry continuously, say, 1200 amp d-c at full voltage of 250 v (with no phase retard, or with a small amount of it), it may be good for carrying something less than 1200 amp at very much reduced voltage.

D-C POWER REQUIREMENTS OF STUDIOS

The primary purpose of d-c supply is to take care of lighting requirements. Since many of these lights are of high intensity, the use of arc lights is indicated. To avoid any noise or whistle associated with a-c arc lights (and this noise would be picked up by the sound track), the use of d-c arcs is imperative. Even with d-c used, special attention should be given to the ripple which might exist in the voltage curve, since even a small ripple might be recorded as noise. This is particularly true in Technicolor practice when the light intensity is much higher than average.

A d-c arc requires about 90–100 v for its maintenance and calls for a ballast resistance for arc stability. In order to save on distribution copper, it is customary to provide a 125–250-v, 3-wire power supply and distribution, with arc lights being connected between the line and neutral leads.

Three-unit sets, with two 125-v generators connected in series and driven by one synchronous motor, have been and are widely employed.

Large studio establishments have many stages, several of which may be in operation simultaneously; it is then customary and logical to install several motor generators in a centrally located substation supplying d-c power to the stages by means of buses. In this manner advantage is taken of the load diversity factor between the several stages, and better continuity of service is assured by having one or two spare units in this central location. Substations with 6, 8, or even

10 motor-generator sets, each of capacity up to 500 kw, are encountered. Of course, if the area to be covered is too large, and blocks of power to be transmitted are appreciable, then more than one substation can be readily provided.

In many instances portable motor generators, mounted on rubber-tire trailers, are successfully employed. They can be readily moved from place to place wherever work is being carried, and this advantage is obvious, particularly for temporary locations.

D-C RIPPLE

A d-c generator is, in effect, an a-c machine, whereby the a-c current generated in the armature is mechanically rectified by the commutator. An oscillograph shows that the d-c voltage thus obtained is not a strictly straight line—like a storage battery would supply, for instance—but includes many small ripples. The ripple on commercial generators of fairly large size is usually kept under 2-3 per cent.

The predominating frequency of the ripple is produced by the armature slots. To minimize the ripple the designers take recourse to the skewing of the slots, or to proportioning of the slot pitch and the pole arc. By these and other means special machines can be produced for studio work whereby the ripple is reduced to about $^1/_2$ per cent. A further reduction of the ripple is usually obtained by external filters, located in the generator leads or in the feeders, and at times in series with the individual lights.

POSSIBLE RECTIFIER ARRANGEMENT FOR STUDIOS

Three-Wire Arrangement.—If a rectifier is considered for this 3-wire service, with as good results as with motor-generator sets, careful attention should be given to the number of phases used.

If it is necessary to operate each 125-v half of the equipment independently, then the ripple should be also taken care of for each half separately.

Fig. 18 illustrates an arrangement made for a 500-kw, 125–250-v unit. The transformer has 2 cores mounted in one tank, each core with a separate primary winding, one—delta, the other—wye. With the secondary windings connected as shown, we have, in effect, 12 tubes in each 125-v circuit. Each of the 4 secondary windings is connected to a 6-tube group similar to the arrangement on Fig. 16. The positive and the negative terminals of each rectifier group are interconnected, as shown, through reactors, acting as interphase transformers. The neutral bus is connected to the neutrals of transformer secondaries.

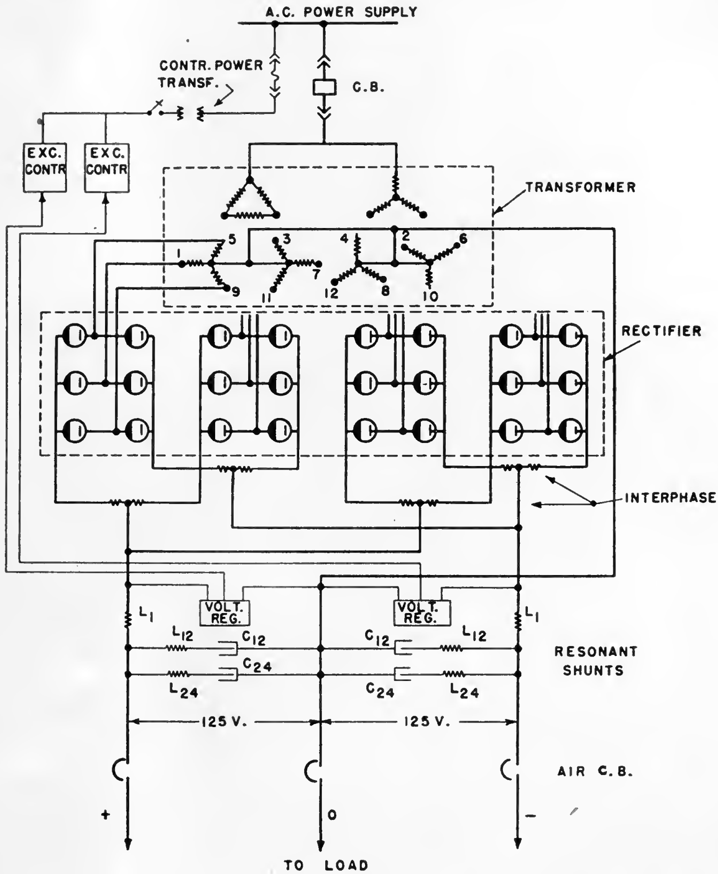


FIG. 18. Arrangement of a 500-kw, 125–250-v rectifier for supplying power for studio lights. Twelve-phase operation is provided for each 125-v system.

Two voltage regulators and 2 excitation circuits are employed, one for each 125-v side. Each regulator is acting in the previously described manner on the phase shifting of the 12 tanks, connected either to the positive or to the negative bus. With the load varying from zero to 100 per cent normal, and with the a-c supply voltage varying

± 5 per cent, not more than 15 per cent phase retard is needed to maintain a constant d-c voltage, within one per cent of pre-set value.

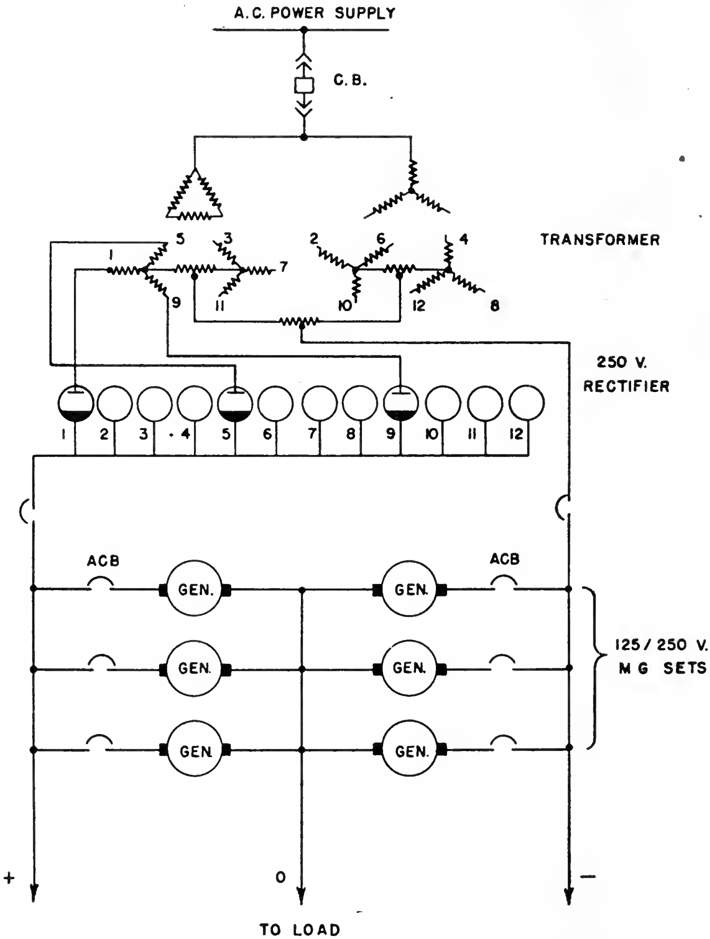


FIG. 19. Arrangement of a 2-wire rectifier operating in parallel with several 3-wire motor generators.

It is worth noting that the rectifier, being an electronic device, has practically no inertia in responding to the voltage regulator.

With this layout, *i. e.*, with a 12-phase circuit used for each 125-v system, the predominant ripple frequency will be 720 cycles and then 1440 cycles, if the power supply is 60 cycles. In order to bring the magnitude of this ripple to a value obtainable with good motor generators, the rectifier will be equipped with a tuned filter, or a resonant shunt, connected as shown to each 125-v system. The reactances L_{12} and L_{24}, and the capacitors C_{12} and C_{24} are selected to "drain off" the 12th and the 24th harmonics in the d-c circuit. The reactors L_1 act as current limitors for this high-frequency current.

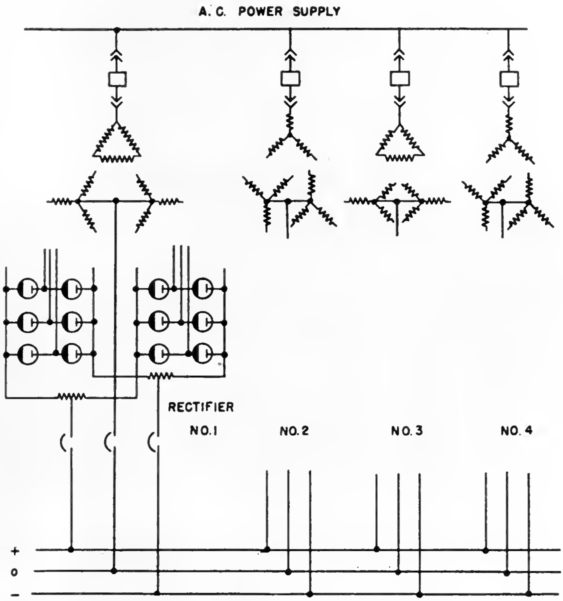


FIG. 20. Rectifier substation with phase multiplication increased by primary connection of transformers.

Voltage Adjustment.—This rectifier can be readily operated at reduced voltage, say down to 50 per cent normal, or still lower if needed. This can be provided by means of phase control, at some sacrifice of d-c form wave. Even then a well-designed tuned filter is capable of keeping the ripple within the acceptable limits.

The following remarks are in order. Arc lights, by their nature, are not operated at voltage, adjustable within wide limits. If wide control of voltage is indicated, as, for instance, for fade-outs or other lighting effects, then incandescent lamps are employed. In this case the problem of d-c ripple affecting the sound track does not exist.

Thus, it seems logical to concentrate on limitation of ripple existing at about normal voltage on the system.

Two-Wire Arrangement.—The 3-wire rectifier just described is self-contained; *i. e.*, it can give complete d-c service independently of other sources of d-c power; it has a sufficient number of phases to keep the ripple under control.

We can consider another case when a rectifier unit is added to an existing 3-wire d-c system of several times the capacity of the new unit. Let us assume that the power supply is now provided by several 125–250-v motor generators (see Fig. 19). If it is feasible to always operate several of these sets whenever the new rectifier is connected to the same bus, then it might not be necessary to make the

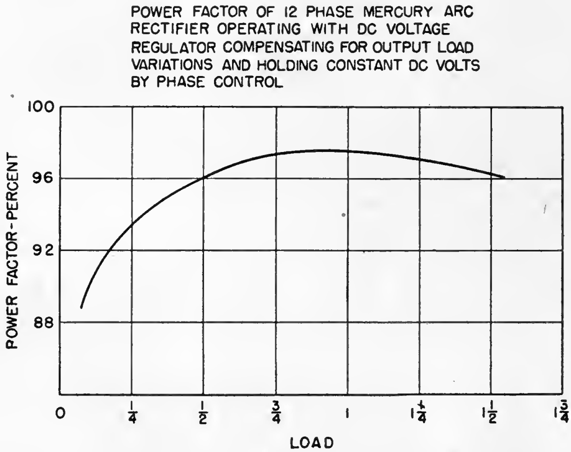


FIG. 21. Power factor of a rectifier; note that it remains high even at light loads.

rectifier of the 3-wire type; a simpler, 250-v, 2-wire unit might be satisfactory. In this case a 12-tube, 12-phase assembly is quite feasible—not greatly different from a conventional industrial rectifier of the same capacity.

Phase Multiplication by Rectifier Groups.—Consider now a brand new installation, say a substation with eight 300-kw, 125–250-v rectifiers, for studio lighting and no motor-generator sets in the same station. It is feasible then to provide the necessary "phase multiplication" for the whole substation rather than for each rectifier. This may offer some advantages in certain specific cases.

For instance, a 300-kw, 125–250-v rating can be readily provided, see Fig. 20, by twelve 200-amp tubes arranged as shown. This gives us only a 6-phase operation either between any one bus and the neutral, or between the 2 outside buses.

By arranging the second 300-kw unit in the like fashion, but with its transformer primary connected wye instead of delta, we get a 12-phase operation when both rectifiers, No. *1* and No. *2*, are operating together. The remaining rectifiers can be arranged likewise and operated in pairs.

If the units involved were of 500-kw, 125–250-v rating, then each would require twenty-four 200-amp tubes for the sake of current carrying capacity, and a 12-phase operation for each 125-v circuit would be available without extra tubes (see Fig. 18). However, even

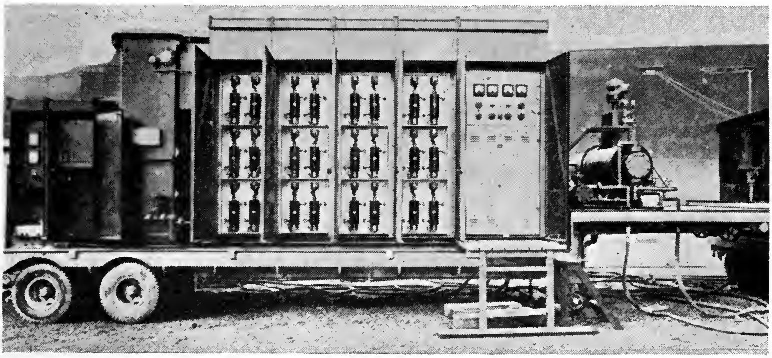


FIG. 22. Portable rectifier substation, rated 500 kw, 125–250 v, used at Navy docks for servicing ships.

then the arrangement in Fig. 20 has the advantage of simpler transformers. On the other hand, it restricts the freedom of the operator in selecting at random the rectifiers which he may wish to connect to the bus at any given time; he should use them in pairs to get a 12-phase performance.

Power Factor.—The power factor of a rectifier is high, but is lagging. It does not fall off rapidly with diminishing load, like, for instance, is the case of an induction motor. It usually is between 90 and 95 per cent, and stays that high down to 25 per cent load or even lower. Fig. 21 illustrates this characteristic of the rectifier.

Parallel Operation.—There is no difficulty in operating a rectifier in parallel either with other rectifiers or with motor-generator sets. Experience in many industries has fully demonstrated that such operation is quite successful. Voltage and load regulators acting on the excitation circuit of the rectifiers take care of this performance.

Mechanical Arrangement.—For units of such capacity as are, and as probably will be, considered for this application, the sealed tube rectifiers are indicated. For the sake of phase multiplication it is to our advantage to use, within economic limits, a larger number of smaller tubes rather than a smaller number of larger units. As we have already seen, a 500-kw, 125–250-v rectifier designed for 12-phase operation in each 125-v leg would be built with twenty-four 200-amp tubes.

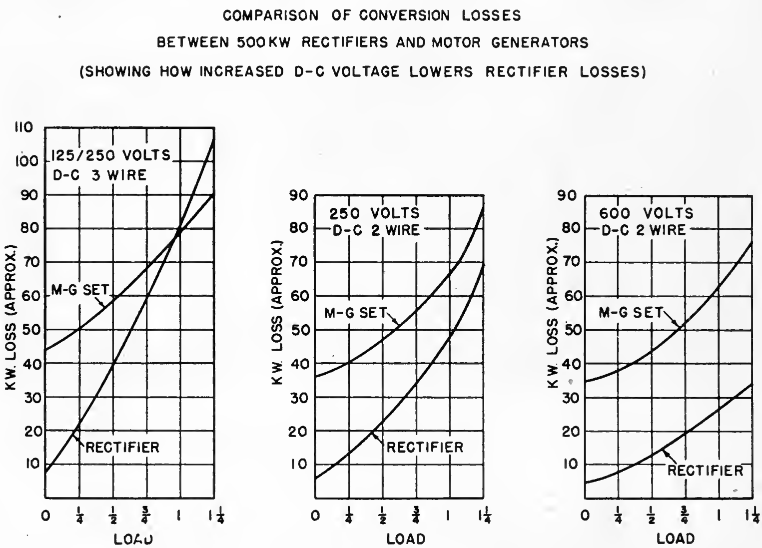


FIG. 23. Effect of d-c voltage on the efficiency of the rectifier.

It is best to build such equipment along the lines which have found full acceptance for other industrial applications of rectifiers. The several tubes are mounted in steel cabinets, with the firing circuits and accessories located in the rear of the same cabinets. The power transformer will be mounted adjacent and will be "throat connected" to the rectifier compartment. The d-c switchgear, voltage regulators, and filters will be located in adjacent cubicles.

This "metal clad" construction consists, therefore, of factory-built units which are completely wired and can be erected with minimum of time at the destination. Since there are no rotating parts involved, no foundation is required.

Fig. 22 illustrates a 500-kw, 125–250-v portable rectifier, one of several units built for Navy docks, to supply d-c power to berthed ships. It shows that similar construction is quite feasible for studio work if a portable unit is called for.

RECTIFIERS VERSUS MOTOR-GENERATOR SETS FOR STUDIO WORK

In this review we have shown that the engineering problems involved in applying rectifiers to the studio d-c power systems can be readily solved. Rectifiers with their associated equipment give a reliable source of power, easily controllable and free of voltage ripple. But so do the motor-generator sets. What, then, should be the basis for the choice between the 2 types of converting equipment?

It should be admitted to begin with that in this competition with the motor-generator set the rectifier starts with a heavy handicap. After all, we are calling for a low-voltage d-c supply, such as 125 v. Thus, for a given kilowatt rating the ampere rating is higher than would be, say, with 250 v, not to speak of still higher voltages. Since the electronic tubes are rated on ampere basis, the low operating voltage calls for a larger number and a larger capacity of tubes. This, obviously, affects the cost.

The 125-v rectifiers are not as efficient as those built for higher voltages, primarily on account of greater effect of the arc drop. Fig. 23 illustrates this fact quite well. However, even then the part-load efficiency is better than with motor-generator sets, and this fact is important in case the load is intermittent.

The low light load losses of the rectifier as compared with rotating equipment may tend to justify the selection of larger units. For instance, instead of having, say, six 300-kw motor-generator sets, it is advisable to provide only four 500-kw rectifiers; it is less important to reduce the capacity of units connected to the bus at times of light load.

The rectifier equipments are easier to install than the rotating equipment. No foundations are required. Motor generators, or the substation where they are installed, should be ventilated, and suitable provisions should be made. On the other hand, the rectifiers are water-cooled. In many cases this arrangement is more satisfactory.

The rectifier substation need not be attended continuously since the entire equipment is stationary. This condition does not necessarily hold true for motor-generator sets.

In case of temporary a-c power failure, the service may be restored quicker with the rectifiers, by simply reclosing the primary breaker. The several motor-generator sets must be restarted and resynchronized, usually one at a time, and this causes delay. In many industrial plants this feature is considered as a definite advantage of the rectifiers.

Thus, the motion picture industry can readily accept the rectifiers as fully suitable for this application. Of course, each specific case should be treated on its own merits to make certain that the best type of equipment has been chosen.

A SMALL MICROPHONE BOOM*

B. F. RYAN AND E. H. SMITH**

Summary.—*A small microphone boom having the versatility and operating controls of all location and other booms is described. The rear end of conventional booms extends substantially beyond the outside of their dollies and the pivot mast protrudes well above the top of the boom pole limiting the overhead clearance. The small boom solves this condition by being so designed and proportioned that with a minimum of overhead clearance and rear end overhang, and together with its special perambulator, it can be used on smaller sets where it is necessary to place the boom in a corner, or to play the transmitter up close to a low ceiling to keep it out of the scene.*

The perambulator frame telescopes to keep within the limits of the boom and to permit easy handling and transportation.

Motion picture settings have always strived for the greatest detail and realism. Owing to wartime restrictions of material, many of the sets are being constructed smaller than it is convenient to photograph and record in. This has required the development of a small microphone boom which can be operated in such small sets without any penalties or handicaps whatsoever in its performance.

The microphone boom described in this paper has been designed to meet the following specifications for use in small sets:

(*1*) It must be adjustable in height so that it may be dollied through a 7-ft door, or be raised so that the operator can see over the lamps and cameras into the set.

(*2*) Its width must be such that it will pass through a 30-in. door, but it must be extremely stable at all times.

(*3*) The boom and its perambulator must be capable of being operated within 30 in. of a wall which is the minimum distance in which a microphone boom operator can stand and work.

(*4*) It must be capable of good pickup as close as 6 ft from the operator, or as far away as 12 ft.

(*5*) It must operate as quietly and with every facility provided by the larger booms in common use.

---

* Presented May 18, 1945, at the Technical Conference in Hollywood.

** Warner Bros. Pictures, Inc., Burbank, Calif.

In Fig. 1, the boom proper consists of a fixed outer steel tube to which all the operating controls are attached. It is mounted in a cast yoke on a horizontal trunnion bearing which permits an up or down movement through an angle of 50 degrees in addition to a horizontal rotation on a vertical bearing in the yoke.

The sponge rubber padded arm rest, as seen in Fig. 2, is held lightly under the operator's left arm by presetting the balance so that the front end is slightly heavy at all times. The cable drum, operated by a hand crank, is of such proportions that 3 complete turns of the

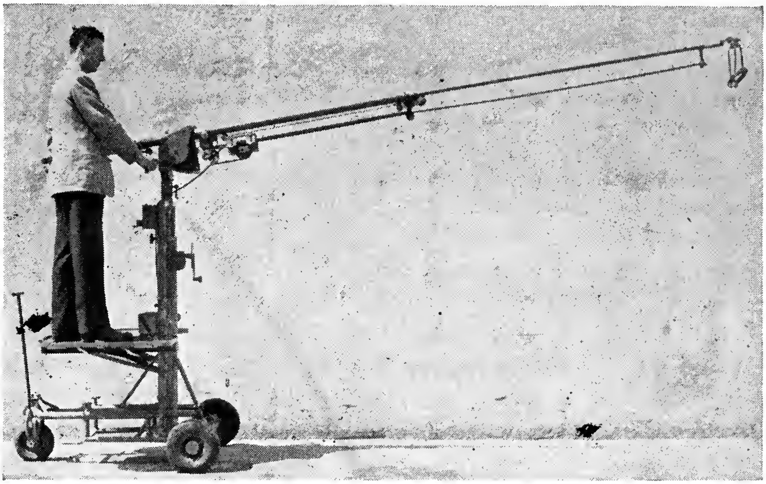


FIG. 1. Side view of small microphone boom with operator in position.

handle will rack the inner boom pole from the closed to the fully extended position, a travel of 6 ft.

The left-hand controls the "twist-gag" handle which, through a single pull cord, rotates the microphone hanger drum, Fig. 3, up to one and one-half turns. The unidirectional microphone, which is customarily used, will then always be in the proper position for the best quality of pickup.

In a further effort to reduce the distance between the top of the pole and the bottom of the microphone, the hanger, Fig. 4, and twist-gag arrangement were redesigned. Fig. 5 shows a partial cutaway section of the hanger and method of control. The microphone is held in a ring clamp that is suspended on rubber shock cord and laced to an outer ring, which in turn is pivoted on a *U*-shaped bracket. This hanger assembly can easily be taken off the drum to change to a "rain hat" hanger by removing a knurled knob. Wind screens are mounted directly on the microphone.

The short "pig-tail" cable is ordinarily held in place in the large hole through the drum bearing by a sponge rubber bushing; however, the cable, being under considerable stress from the oscillating movement of the microphone hanger, may develop an open circuit in the shield, in such case it may be readily replaced. No tools are required, as it has a Cannon plug at one end and a receptacle with a gland nut at the other that may be loosened and the receptacle and cable drawn through the hole.

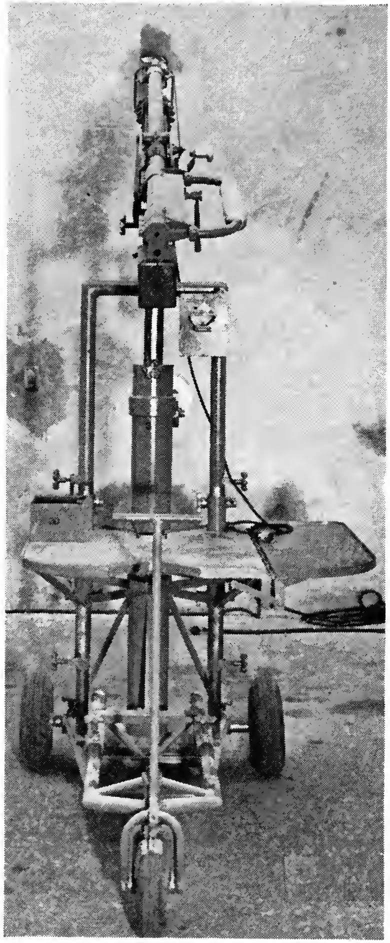


FIG. 2. Rear view of small microphone boom.

One end of the cord used to rotate the assembly is fastened on a fixed sheave bracket then passed over sheaves and around the hanger drum, then down the inside of the boom pole, and finally spliced to a length of rubber shock cord anchored in the pole. The composition of the shock cord being basically rubber, its life is considerably prolonged by placing it within the tube away from light and moisture. This arrangement replaces the former method of a coiled clock spring which had to be covered with a graphite impregnated cotton sleeving and mounted inside the hanger. Though reasonably satisfactory, it was, nevertheless, a source of noise and frequent servicing.

All moving parts on the boom are mounted in babbitt bearings and lubricated by Zerk fittings. This type of bearing material has been found by numerous experiments to give the quietest and most trouble-free service.

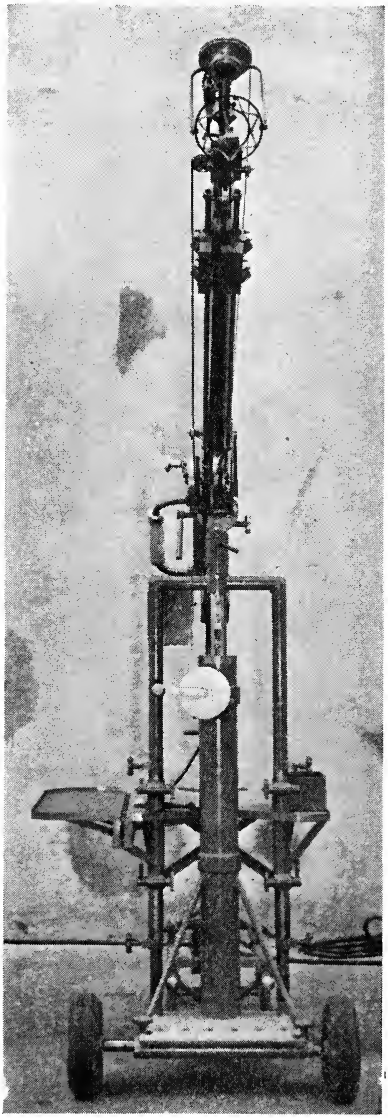


FIG. 3. Front view of microphone boom.

The type and speed of all operating controls are identical with those on the larger booms; thus, the boom man can switch back and forth between the large and small booms without noticeable difference in the feel or manipulation of the controls.

Fig. 6 shows the direct comparison between the Warner Bros. standard size and small booms, both in the closed position. As a standard of comparison, the microphone holder on the small boom is 6 ft from the center post. The small boom has an over-all closed length of 8 ft 6 in. including the rear-end overhang which, at all times, remains within a radius of 30 in. from the center column.

The frame of the small perambulator is of welded steel tubing construction. Though shown in the mid position, the wheelbase is adjustable from an over-all extended length of $4^1/_2$ ft to a closed position of 3 ft, the steering arm nesting in the recess in the platform to keep within the rear-end overhang of the boom.

In Fig. 7 both booms are fully extended. The maximum reach of the small boom from the center post is 12 ft, which is 6 ft less than that of the large boom.

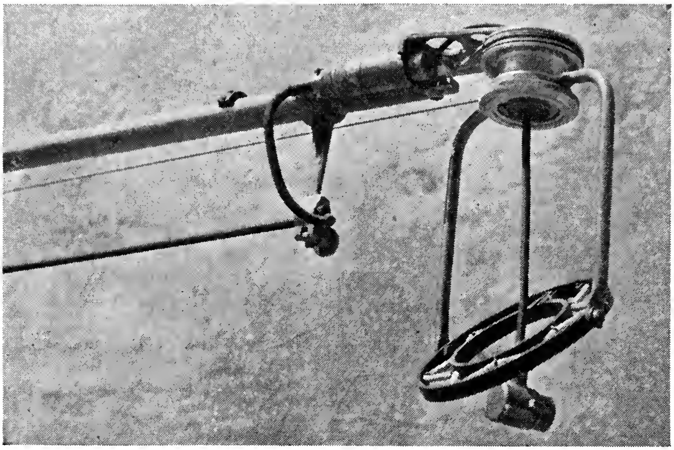


Fig. 4. Microphone hanger.

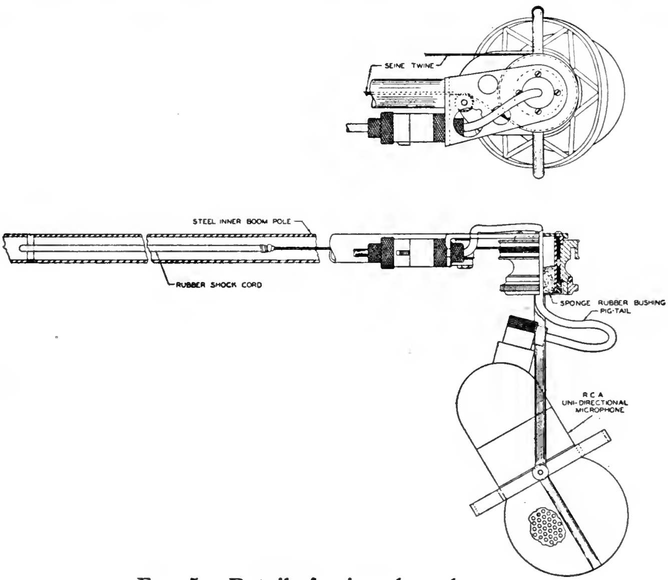


Fig. 5. Detail of microphone hanger.

Fig. 8 shows the final assembly drawing containing the principal dimensions and their limits. A fabric covered flexible steel cable, or standard tiller rope, is wound on an aluminum drum, then reeved over a series of sheaves and secured to the rear end of the inner pole to move it in and out. The cable is also fastened to the counterweight

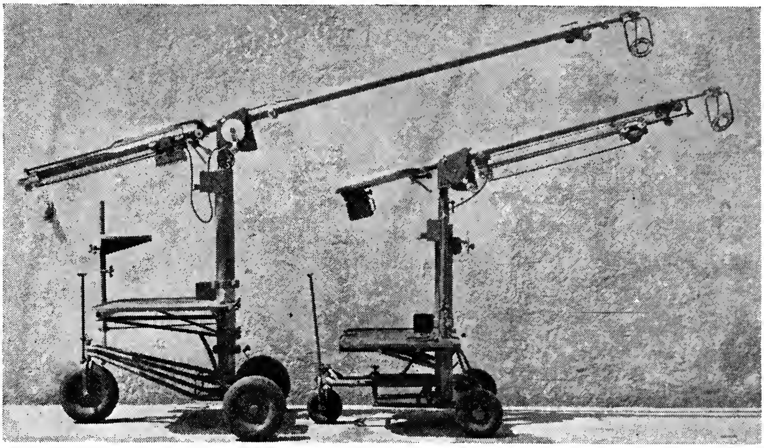


FIG. 6. Comparison of large and small microphone booms; shafts retracted.

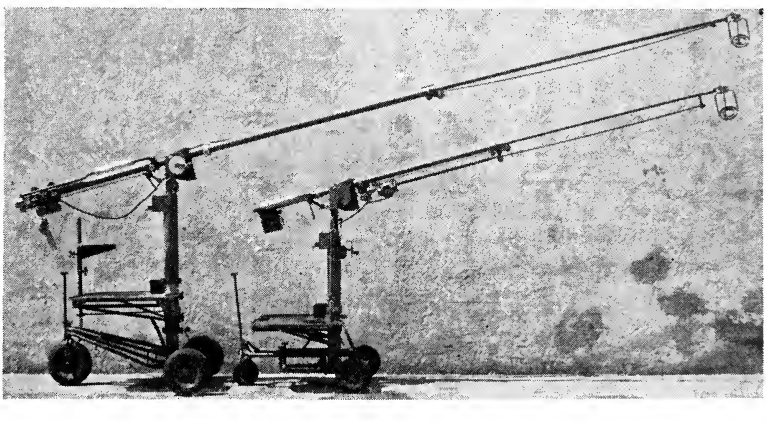


FIG. 7. Comparison of large and small microphone booms; shafts extended.

carriage through a pair of threaded thimbles providing for any necessary adjustment. The trunnion bearing is set 6 in. forward to allow the use of a smaller fixed counterweight. This stationary weight is a 55-lb cast block of lead attached to the rear end of the outer tube and is made removable leaving a net weight of 82 lb for the boom, thus facilitating its handling and transportation.

The traveling counterweight on the boom serves a dual purpose in that it controls the slack in the microphone cable and twist-gag cord, as well as compensates for the out-of-balance condition that develops during the extension of the boom. As it was impractical to mount the traveling weight in the rear and meet the requirement that the boom could operate 30 in. from a wall, the traveling weight was placed in front of the vertical shaft.

The carriage rides through rubber guide rollers on 2 small steel tubes suspended from the underside of the large outer tube. A two-

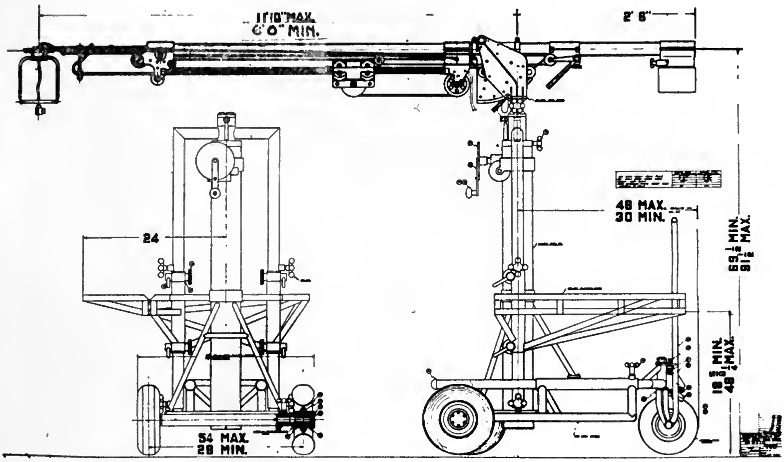


FIG. 8. Dimensional drawing of small microphone boom.

to-one ratio was necessary to move the carriage, and it was obtained by placing another grooved drum in the center of the trunnion fork and on the same shaft with the main cable drum, but having exactly one half its pitch diameter. The original arrangement, with the carriage forward and the boom fully in, is balanced by the fixed weight on the rear end. The weight of the carriage, however, had to be such that its moment would decrease by the same amount as the moment of the inner pole increased when it was boomed out and vice versa.

In order to obtain the most advantages from this type of boom it was necessary to design a special perambulator that combined stability with the ability to be collapsed to smaller proportions and thus remain within the limits of the boom. In this condition it would be possible for an operator to ride on the platform with the drop leaf folded back and control the boom while it is being dollied through a 30-in. door which is 6 ft 8 in. high. By means of the crank on the center column operating through a self-locking worm and rack and pinion, the boom can be raised to a maximum height of 7 ft $9^1/_2$ in. above the floor. Steering is accomplished through a forked tee handle mounted on the rear caster wheel. The parking brake consists of a shoe operated by a cam mechanism and is applied to the tire automatically when the steering handle is latched in the vertical position, but may be readily released by a downward pressure on the catch.

Primarily the small-type boom was designed for use where space limitations brought about a condition whereby it was impractical to use the standard boom. However, this does not preclude a broad useful field for this boom, as emphasis was placed upon standardization of most parts and accessories in order that they could be freely interchanged, any boom fitting any perambulator, and, if necessary, they will fit the standard lamp tripod.

A NEW CARBON FOR INCREASED LIGHT IN STUDIO AND THEATER PROJECTION*

M. T. JONES, R. J. ZAVESKY, AND W. W. LOZIER**

Summary.—*A crater brightness of as much as 1400 candles per sq mm is produced by a new 13.6-mm super high-intensity positive carbon. This brightness is obtained at 290 amp using water-cooled jaws of special design. With conventional positive carbon jaws, a crater brightness of 1200 candles per sq mm is obtained at 265 amp. The burning rate of the positive carbon in both cases is approximately 45 in. per hr.*

Tests of these carbons with a relay condenser optical system indicate possibility of a 30 to 45 per cent increase in quantity of screen light for transparency process projection. Measurements with a standard condenser optical system of the type used in theater projection show increases of 40 to 60 per cent over standard carbons. Mention is made of the necessity of adequate provisions in order that the components of the projection system can accommodate the faster burning rate, higher power and higher intensity of radiant energy associated with the operation of the new carbons.

Technological developments of the past 10 years have resulted in a succession of advances which have increased several fold the quantity of light which can be projected on a motion picture screen. This is true both for transparency process projection[1, 2] in the motion picture studios, and also for projection in motion picture theaters. These advances have resulted from improvements of the various components of the projector system including the carbon arc light sources,[3, 4, 5] arc lamps, optical systems, projectors, *etc.* Present theater projection systems make it possible to project 2 to 3 times as much light to the screen as was possible 10 years ago. Light levels with modern studio transparency process projection equipment can be as much as tenfold those of a few years ago. However, the industry has used all the light that is available and has expressed a desire for more. This paper will demonstrate that still further increases in screen light can be obtained owing to the recent development of a new 13.6-mm experimental positive carbon which operates with a higher crater brightness than any carbon commercially available at

* Presented May 14, 1945, at the Technical Conference in Hollywood.

** National Carbon Company, Inc., Fostoria, Ohio.

the present time. This new 13.6-mm super high-intensity positive carbon is a result of intensive research and development work performed during the past few years and directed toward the goal of higher brightness.

Operating Characteristics.—This paper is concerned with the type of high-intensity arc and carbons wherein the positive carbon is rotated during burning and the negative carbon is placed at an angle with respect to the positive. At the present time standard

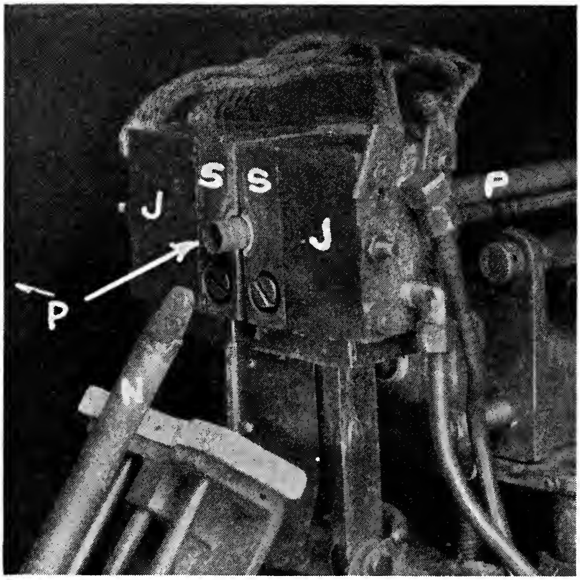


FIG. 1. Special water-cooled jaws for positive carbon showing *S*, silver contact blocks; *J*, water jacket; *P*, positive carbon; and *N*, negative carbon.

National 13.6-mm super high-intensity projector positives[3] and National 16-mm super high-intensity studio positive carbons[5] are employed to provide the highest levels of screen illumination for background projection, and the 13.6-mm carbons to give the maximum screen light for theater projection. These 13.6-mm and 16-mm carbons operate at 170 amp and 225 amp, respectively. In comparison, the new 13.6-mm super carbons have been burned at currents up to approximately 290 amp.

Research has shown that the brightness of the high-intensity carbon arc depends, among other things, upon the density of current entering the crater. Increased current density signifies greater concentration of electrons, positive ions and excited atoms in the crater gases which are the principal source of light. Following this principle, carbon compositions and methods of burning have been developed which allow a much greater dissipation of energy per unit area within the crater and results in increased brightness. The new 13.6-mm positive carbon has been designed in this fashion. It has been operated at currents up to approximately 265 amp in lamps with conventional air-cooled positive jaws.

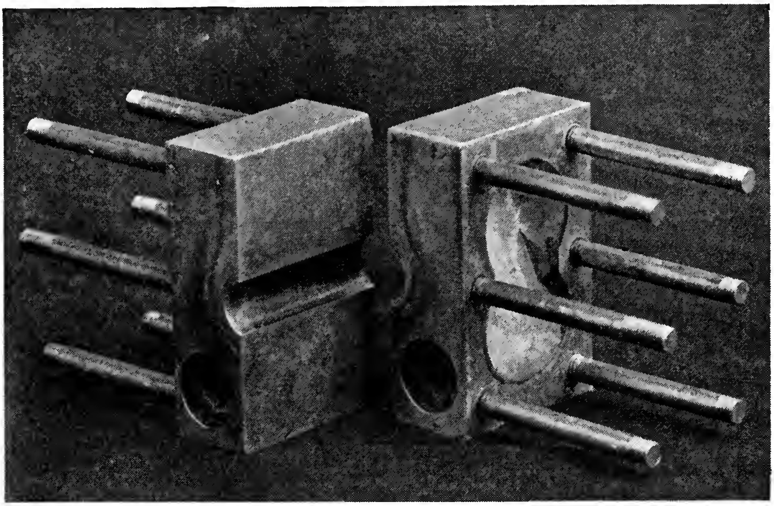


Fig. 2. Close-up of silver contact blocks and mounting studs.

However, the composition of the new 13.6-mm super carbon is such that its maximum current rating can be extended to currents higher than 265 amp by employing methods which will more effectively cool the positive carbon. One means of accomplishing this result has been the use of water-cooled jaws of a special design in combination with a short protrusion of the end of the positive carbon beyond the jaws. The important features of this design are illustrated in Fig. 1. The cooling water in the jackets, *J*, comes into direct contact with the silver blocks, *S*, which fit snugly around the positive carbon, *P*. Fig. 2 shows in more detail the design and construction of the silver contact blocks. This design coupled with the high conductivity of silver permits unusually rapid removal of heat from the carbon.

Flow rates of water of approximately one gallon per min are more than ample to take care of any of the operations described in this paper.

A new $^5/_8$-in. copper-coated negative has been developed to operate with the new 13.6-mm carbon. This negative carbon can be used in the conventional manner. Another type of negative also has been de-

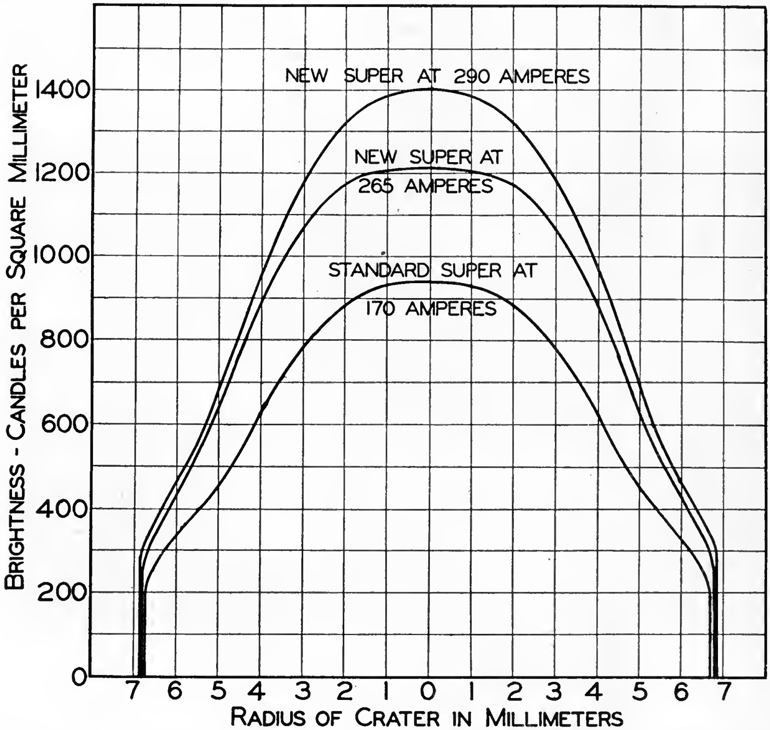


FIG. 3. Distribution of brightness across crater of 13.6-mm super high intensity carbons.

veloped for use with the new positive carbon. This is an unplated 7-mm negative carbon which is designed to operate in special water-cooled jaws. This type of negative carbon has ample current-carrying capacity for operation over the 265–290-amp range. The absence of a copper plate eliminates any possibility of copper drippings adhering to the lamp optical system. The cooling water dissipates heat which otherwise would be absorbed by lamp parts. Improved arc stability is obtained through use of the smaller diameter negative carbon.

TABLE 1

Operating Characteristics of Carbon

Positive Carbon	Negative Carbon	Positive Carbon Jaws	Protrusion of Positive Carbon	Amp	Volts	Burning Rate of Positive Carbon—In. Per Hr	Crater Cp
Standard 13.6-mm Super High-Intensity Projector	"Orotip" $1/2$-in. Heavy Duty	Air-cooled or Special Water-cooled	$1\,3/8$ in.	170	75	22	78,000
Standard 16-mm Super High-Intensity Studio	"Orotip" $17/32$-in. Heavy Duty	Air-cooled or Special Water-cooled	$1\,3/8$ in.	225	75	22	95,000
New 13.6-mm Super High-Intensity	New $5/8$-in. Copper Coated	Air-cooled or Special Water-cooled	$1\,3/8$ in.	265	80	45	106,000
New 13.6-mm Super High-Intensity	New $5/8$-in. Copper Coated	Special Water-cooled	$1/2$ in.	290	80	45	116,000

Note.—Lamp operated with negative at an angle of 53 degrees below the positive and with a $7/8$-in. arc length between the tip of the negative and the center of the positive crater face.

Studies have been made in a laboratory test lamp on the burning performance of the new 13.6-mm super carbons in comparison with the standard 170-amp 13.6-mm and 225-amp 16-mm super carbons. Crater brightness and total crater candlepower were measured using the method and equipment recently described.[6] The 3 types of carbons were operated both with air-cooled and with the special water-cooled positive carbon jaws. The results are given in Table 1 and Fig. 3.

Fig. 3 shows the brightness distribution across the crater for the 13.6-mm carbons. The new 13.6-mm carbon at 265 to 290 amp has a brightness at the center of the crater ranging approximately from 1200 to 1400 candles per sq mm. These values, respectively, are about 30 and 50 per cent greater than the brightness of the 170-amp 13.6-mm carbon. A maximum operating current of 265 amp was obtained for the new 13.6-mm carbons with a $1^3/_8$-in. protrusion both with air-cooled jaws and with special water-cooled jaws described above; the burning characteristics were practically identical with both types of jaws. However, a reduction in protrusion to $^1/_2$ in. with the special water-cooled jaws allowed the maximum operating current to be increased to 290 amp.

Some insight into the significance of the combination of water-cooled jaws and short protrusion may be obtained from measurements of the amount of heat carried away by the cooling water. With a positive carbon protrusion of $^1/_2$ in. and a current of 290 amp, the amount of power carried away as heat by the cooling water was 4.2 kw which is approximately 18 per cent of the input power to the arc. When the protrusion was increased to $1^3/_8$ in. with a current of 265 amp, the power carried away as heat decreased to 2.8 kw which is 13 per cent of the arc power. This difference in heat transfer by the cooling water made it possible to burn the new carbon at the higher current.

The data in Table 1 show that the burning rate of the new 13.6-mm carbon is 45 in. per hr, or approximately double that of the standard 13.6- and 16-mm carbons. It is significant to note that there was no increase in burning rate of the new 13.6-mm carbon with the increase in current from 265 to 290 amp. The explanation for this observation undoubtedly rests on the improved cooling and reduced oxidation afforded by the decrease in protrusion which accompanied the change in current.

Application of New Carbons to Transparency Process Projection.—There is general recognition of the important role of transparency process projection in modern motion picture production. Although improvements in recent years have greatly expanded the usable area of process projection screens, the present possibilities are often less than desired. It was visualized that the new 13.6-mm super carbons might offer a significant improvement in quantity of screen light available for background projection. Consequently, arrangements were made to obtain information on this point.

Through the cooperation of Farciot Edouart of Paramount Studios, Hollywood, we were able to test the new 13.6-mm carbons in the Paramount transparency process projection equipment. This equipment contains the Paramount design of relay condenser system which has shown such merit in process projection. This equipment also employs the Mole-Richardson arc lamp designed to Academy Research Council Process Projection Specifications. This lamp utilizes water-cooled positive carbon jaws and head and the positive carbon protrusion from the jaw was $1^5/_8$ in. Under these conditions it was found that the new 13.6-mm super positive carbon and $^5/_8$-in. negative carbon could be burned at currents as great as 265 amp. As bases of comparison, tests were also made with the commonly used 16-mm super high-intensity studio positive at 225 amp, and with the 13.6-mm super high-intensity projector at 170 amp. The steadiness of the light was practically equivalent on all carbons at the indicated currents. The results of the measurements are given in Table 2 and show that the new carbon offers approximately a 30 per cent increase in screen light over the 16-mm standard carbon at 225 amp, and a 45 per cent gain over the 13.6-mm 170-amp carbon. Distribution of intensity on the screen was good and was quite comparable with all the combinations employed.

TABLE 2

Screen Light for Transparency Process Projection

Positive Carbon	Amp	Relative Screen Lumens*
Standard 13.6-mm Super High-Intensity Projector	170	90
Standard 16-mm Super High-Intensity Studio	225	100
New 13.6-mm Super High-Intensity	265	130

* Measured at Paramount Studios with relay condenser system and silent camera aperture (0.723 in. × 0.980 in.).

This new carbon, which offers increases in illumination of from 30 to 45 per cent over that obtainable from present standard carbons, should make available a significant increase in usable screen area. It is estimated that an additional 10 to 15 per cent increase in screen light would be expected from operation at 290 amp which can be made possible as described above.

Application of New Carbons to Motion Picture Theater Projection.—The new 13.6-mm positive carbon was also considered with respect to the quantity of screen light available for 35-mm film projection with a standard condenser optical system such as used in theaters. The 13.6-mm super high-intensity projector carbon and the new 13.6-mm carbon were compared in laboratory tests using a standard 35-mm film aperture and *f*/2.2 condensers (operated at *f*/2.0 distances) and with a treated 5-in. focal length *f*/2.0 projection lens. As shown in Table 3, the measured screen light without shutter or film was increased from 18,500 lumens for the 13.6-mm 170-amp carbons to 26,000 lumens with the new 13.6-mm positives operated at 265 amp and to 30,000 lumens at 290 amp. This should make available 40 to 60 per cent more screen light than the maximum now obtainable.

TABLE 3

Screen Light for Motion Picture Projection

Positive Carbon	Positive Carbon Jaws	Protrusion of Positive Carbon	Amp	Screen Lumens*	Maximum Intensity of Radiant Energy at Center of Film Aperture—Watts Per Sq Mm**
Standard 13.6-mm Super High-Intensity Projector	Air-cooled or Special Water-cooled	1 3/8 in.	170	18,500	1.05
New 13.6-mm Super High-Intensity	Air-cooled or Special Water-cooled	1 3/8 in.	265	26,000	1.45
New 13.6-mm Super High-Intensity	Special Water-cooled	1/2 in.	290	30,000	1.65

* At 80 per cent side to center distribution without shutter, film or filters, and with standard 35-mm (0.600 in. × 0.825 in.) aperture; *f*/2.2 condensers and *f*/2.0 treated projection lens.

** Radiant energy measurement made with system adjusted to give maximum intensity at center of film aperture.

Determinations of the intensity of radiant energy incident at the center of the film aperture were made with the 13.6-mm super and the new 13.6-mm carbons in the above condenser optical system. The technique used was the same as described in a recent paper[7] and involves the use of a pinhole aperture, thermopile, and filters. The intensity of radiant energy is listed in Table 3 in combination with the screen light data obtained. With the new 13.6-mm positive the maximum intensity at the center of the film aperture is 1.45 to 1.65 w per sq mm compared with a value of 1.05 w per sq mm for the standard 13.6-mm super high-intensity projector positive carbon system. By using a heat filter[7] it is possible to reduce markedly the total energy flux at the film aperture with a smaller reduction in light intensity. There are filters which reduce the total radiant energy approximately 50 per cent with a light reduction of perhaps 20 per cent. With such a filter, the total radiant energy incident at the center of the film aperture can be reduced to nearly the same level as for 125-amp standard 13.6-mm condenser systems with approximately twice as much light.

With a heat filter of 80 per cent light transmission, a 90-degree film shutter and 75 per cent screen reflectivity, the 290-amp operation should yield a brightness of 12-ft-L, the approximate average of the ASA Standard range, at the center of a screen 35 ft in width which is 25 per cent wider than can be illuminated to this intensity with the 170-amp 13.6-mm carbon.

It must be recognized that adequate provisions must be made so that all the components of the projection system will accommodate the special features of the new carbons. For example, the lamp must be adapted to the faster burning rate of the new carbons. The lamp parts, the condenser lenses, and the projector parts near the aperture must be able to withstand the increased heat from the arc. Heat filters or other provisions will be necessary to prevent undesirable effects caused by heat on the film. When these factors are properly taken into account, these new carbons will offer noteworthy increases in light for projection.

REFERENCES

[1] EDOUART, F.: "The Paramount Transparency Process Projection Equipment," *J. Soc. Mot. Pict. Eng.*, **XL**, 6 (June, 1943), p. 368.

[2] EDOUART, F.: "High-Efficiency Stereopticon Projector for Color Background Shots," *J. Soc. Mot. Pict. Eng.*, **XLIII**, 2 (Aug., 1944), p. 97.

[3] JONES, M. T., LOZIER, W. W., AND JOY, D. B.: "New 13.6-Mm Carbons for Increased Screen Light," *J. Soc. Mot. Pict. Eng.*, **XXXVIII**, 3 (Mar., 1942), p. 229.

[4] LOZIER, W. W., CRANCH, G. E., AND JOY, D. B.: "Recent Developments in 8-Mm Copper-Coated High-Intensity Positive Carbons," *J. Soc. Mot. Pict. Eng.*, **XXXVI**, 2 (Feb., 1941), p. 198.

[5] JOY, D. B., LOZIER, W. W., AND NULL, M. R.: "Carbons for Transparency

Process Projection in Motion Picture Studios," *J. Soc. Mot. Pict. Eng.*, **XXXIII**, 4 (Oct., 1939), p. 353.

[6] JONES, M. T., ZAVESKY, R. J., AND LOZIER, W. W.: "Methods for Measurement of Brightness of Carbon Arc," *J. Soc. Mot. Pict. Eng.*, **45**, 1 (July, 1945), p. 10.

[7] ZAVESKY, R. J., NULL, M. R., AND LOZIER, W. W.: "Study of Radiant Energy at Motion Picture Film Aperture," *J. Soc. Mot. Pict. Eng.*, **45**, 2 (Aug., 1945), p. 102.

A NEW PHOTOGRAPHIC DEVELOPER FOR PICTURE NEGATIVES*

J. R. ALBURGER**

Summary.—*A new developer formula is described which has the property of resisting the effect of bromide while maintaining good characteristics suitable for picture negatives. This developer may be replenished in the same manner as ordinary positive developers. By use of this formula the H and D characteristic is held essentially constant, and control is maintained over the effective emulsion speed of the developed film. As much as 100 per cent increase in emulsion speed may be obtained while maintaining gamma and grain structure comparable to normal commercial negative developers.*

In 1940 at the spring meeting of the Society of Motion Picture Engineers, in Atlantic City the author had the opportunity to present a paper on the subject of "Mathematical Expression for Developer Behavior."[1] In that discussion the object was to derive some indication as to the optimum chemical structure for a developing agent which is required to have given characteristics suitable for picture negative development. At a somewhat later date, the application of these theoretical considerations resulted in the selection of a molecule which should have approximately the desired characteristics. By a strange coincidence, when the material was prepared and combined in a developer formula it had almost exactly the characteristics which were suggested by the theory.

Unfortunately, as is usually the case, there were certain undesirable features to the developer thus produced and it required extensive study to bring forth a commercially usable formula. The various unusual characteristics of this formula are to be the subject of the present paper. The formula will be designated by the coined term "Reidol Formula."

In present laboratory practice it is desirable that a picture negative developer produce a gamma of 0.6 to 0.7 while maintaining a high

---

* Presented May 17, 1945, at the Technical Conference in Hollywood.

** Hollywood, Calif.

level of emulsion speed and a relatively fine-grain structure. One serious difficulty with practically all negative developers is their sensitivity to bromide. Bromide ions are released into solution by the chemical reaction of development. The photosensitive silver bromide is reduced to metallic silver and the bromide ions remain in the solution.

The presence of bromide in the solution acts to depress the intersection point of the H and D family. This results in loss of toe densities or shadow detail and in a change of the contrast of the developed image.

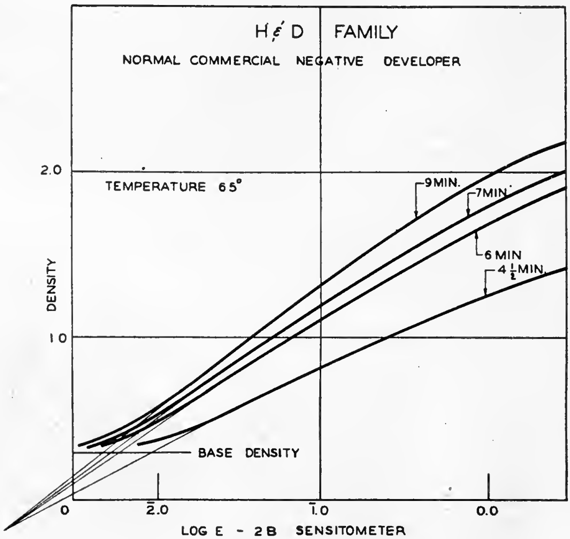


FIG. 1.

It would appear that a highly desirable state of affairs would exist if a developer formula could be found which was relatively insensitive to the presence of bromide. In Fig. 1 there is shown an H and D family for a representative commercial negative developer without bromide. Addition of bromide to this developer would seriously hamper its operation. Fig. 2 shows the result of adding 3 grams per liter of KBr to this solution.

Fig. 3 shows a similar H and D family for the Reidol formula in which is contained 3 grams per liter of KBr. The intersection point of the H and D family is actually higher than that of the normal commercial developer without bromide of Fig. 1.

A number of interesting results are obtained with the Reidol formula, or certain modifications of the formula. The stability with respect to bromide results in increased emulsion speed for a given gamma as compared with commercial developers. This is partly because of the fact that it is possible to work the Reidol formula at its highest efficiency at all times. There is in addition the fact that the Reidol formula is inherently of a lower gamma-infinity than most commercially used developers.

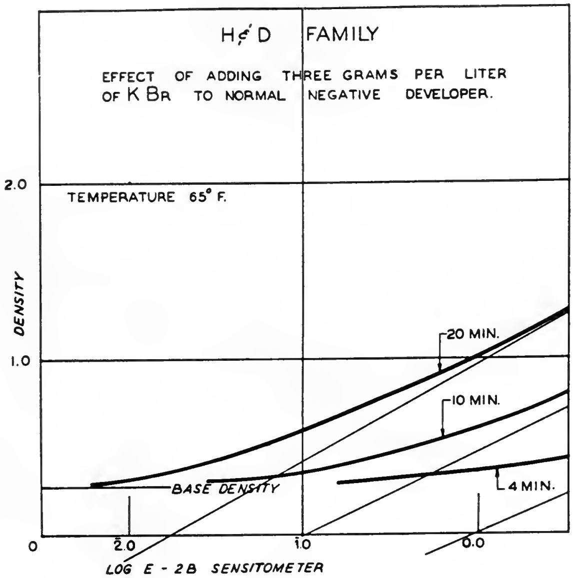


FIG. 2.

With a concentration of the order of 3 grams per liter of KBr, it is apparent that the small increments of bromide which are generated during the development of film will exert relatively little effect on the action of the developer. This characteristic may be advantageous in the elimination of the so-called "bromide drag" which sometimes causes objectionable streaks in negatives.

By maintaining a balance of bromide concentration in the solution it should be possible to develop several thousand feet of film in each gallon of developer solution, provided, of course, a proper concentration of developing agent is present to prevent chemical exhaustion. There seems to be every possibility of establishing a workable commercial procedure wherein a simple replenisher is added only to the extent of carry-over. As long as the bromide content is kept near an equilibrium point the developer will continue to act at its maximum efficiency.

Fig. 4 shows the behavior of the Reidol formula with respect to exhaustion. In this test fully exposed film was developed to a density of about 2.4. Since the average negative density (over the whole film) is approximately 0.6 it means that every 10 ft of fully exposed

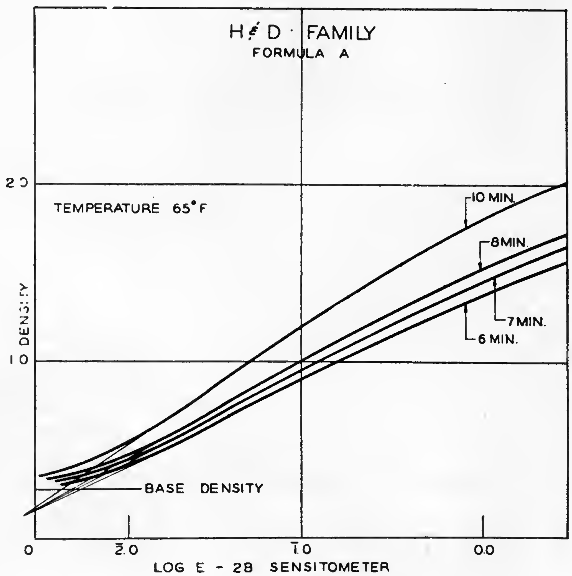


FIG. 3.

film is equivalent to 40 ft of normal negative film. The assumption was made that the developer is to be consumed at the rate of one gallon per thousand feet of film. Accordingly, replenisher solution without bromide was added to replace the used developer at the rate of about 100 cc for each 10 ft of fully exposed film. It should be noted that following an initial loss of speed, the developer characteristic levels off to a practically constant value.

This exhaustion test is only indicative of the possible conditions to be encountered in commercial operations. Somewhat different behavior is to be expected in practice since other factors will enter, such as aerial oxidation and variations owing to rate of replenishment.

The Reidol formulas operate at *p*H values of 7.5 or less. The developer will still function at *p*H values as low as 5.5. Variations of the formula may be compounded by adding buffers or weak acids, or by altering relative concentrations, and a wide range of characteristics may be obtained by the choice of different operating conditions.

In Fig. 5, H and D curves are shown for several conditions of time, temperature, and modifications of the formula. It can be seen, therefore, that desired characteristics may be obtained under almost any conditions of laboratory practice.

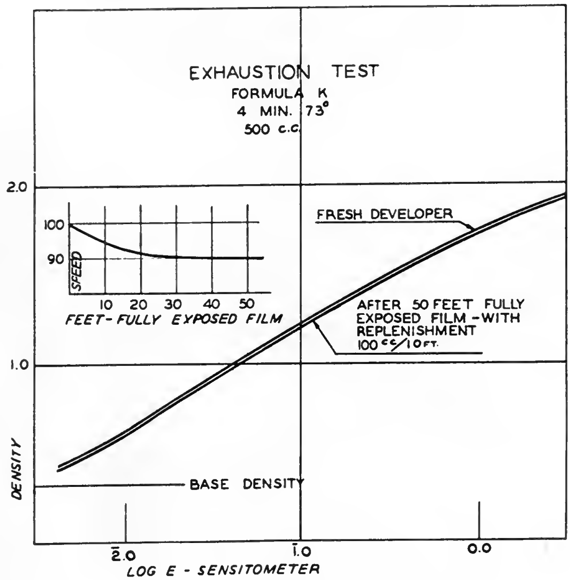


FIG. 4.

One suggestion which was made at the outset is that the additional emulsion speed which it is possible to derive from the Reidol formulas would be of value to the studios in simplifying lighting problems. This may well be, but it is only fair to state that the additional speed may be detrimental in certain cases. For example, an outdoor scene may be so bright that the lens must be stopped down to a point where the image suffers. The very next scene may be one where the maximum film speed is none too great. For practical considerations, this wide range of requirements must be handled by one film.

By use of certain of the Reidol formulas, it is possible for the cameraman to choose the emulsion speed at which he wishes to operate. By subsequently employing the appropriate development procedure it is possible and even quite practical to develop the films to the desired characteristic. This may all be done in the same developer solution and at the same temperature. The cameraman, therefore, has control over the speed of the film he is using and, effectively, he is given a variety of different films in the same can. The control is effective over a range of more than two to one in speed.

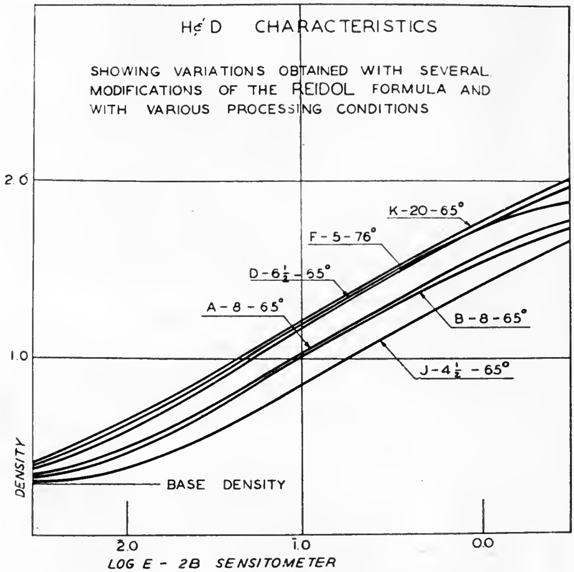


FIG. 5.

Fig. 6 shows the possible variations in speed as obtained with the Reidol formula.

The grain structure of the developed image is comparable with that obtained from other commercially used picture negative developers. The images have a slightly brownish cast which is characteristic of fine-grain developers. There is more fog developed by the Reidol formula than normal since the energy is quite high. However, this so-called "veil" is constant and does not impair the image quality. The important factor in film speed is, of course, the difference between the base or fog density and the actual image density. If the ultimate of emulsion speed must be obtained, then a certain degree of fog is inevitable.

Owing to the fact that the active ingredients are not commercially available, they must be synthesized in the laboratory for experiments on the scale of preliminary tests such as these. However, the synthesis of the materials is relatively simple so that in the event the formula finds reasonable use in the industry the cost of the formula would be comparable to presently used commercial developers.

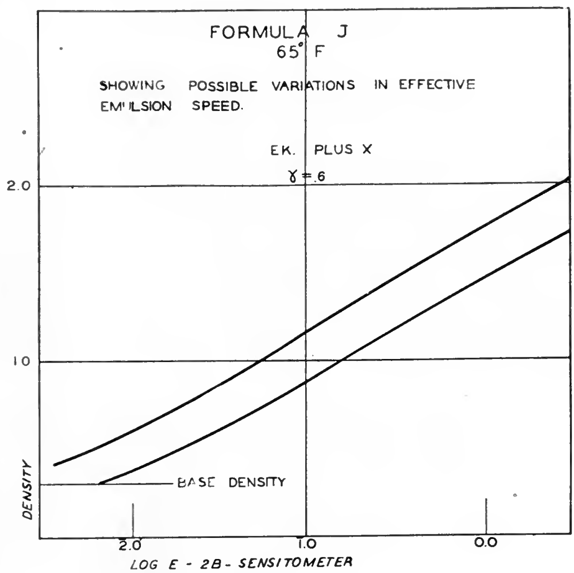


FIG. 6.

A toxicity test was carried out by the author wherein a pad of cotton soaked in the developer solution was taped to the underside of the arm for a period of 14 hr. No effect of any kind was observed; not even a discoloration of the skin. There is, of course, the possibility that certain individuals may be sensitive to the chemical content of the Reidol developer. However, in view of the fact that the *p*H of the developer is near neutral and that the salt concentration is such that near isotonic solutions are obtained, it is reasonable to expect that little difficulty will be had on this score.

All H and D tests were made with Eastman Kodak Plus-*X* film.

REFERENCES

[1] ALBURGER, J. R.: "Mathematical Expression of Developer Behavior," *J. Soc. Mot. Pict. Eng.*, XXXV, 3 (Sept., 1940), p. 282.

A POSITIVE VARI-FOCAL VIEW-FINDER FOR MOTION PICTURE CAMERAS*

FRANK G. BACK**

Summary.—*Vari-focal view-finders now in use change the field which corresponds to the field covered by the camera lens either mechanically or optically. Mechanical systems change the area of the image seen through the view-finder and therefore produce small images when used with telephoto lenses. The optical view-finders now in use are either negative systems, which do not allow the image produced by them to be framed properly, or they also change the area of the image.*

The new view-finder consists of a vario-focal system with movable lenses producing real images corresponding to the different fields of the motion picture lenses at infinity, which are viewed through a stationary erector system. They therefore can be framed and the frame being inside the erector system always appears the same size regardless of the focal length of the view-finder.

A new positive Vari-Focal view-finder for motion picture cameras eliminates the disadvantages of the 2 classes of finders now in use. The new view-finder uses only *positive* elements, thereby producing an upright real image. And it is possible to secure this real image in a frame of constant size. The image becomes variable over a wide range along a smooth and continuous curve instead of by intermittent steps as is the case in some other types of finders.

The 2 classes of finders presently used secure images by 2 different methods. One limits the fields of the different camera lenses by mechanically changing the size of the frame which surrounds the image. The second class changes the field by optical means.

In the first class, we see that the image frame gets smaller as the focal length of the camera objective increases. The disadvantages of this are apparent. Those finders of the second class which change the field optically do one of two things: they change the frame size, as in the first class, or they produce only virtual images which do not frame distinctly. Negative-type finders, as described, also have

---

* Presented May 16, 1945, at the Technical Conference in Hollywood.

** M.E., Sc.D., Research and Development Laboratory, 381 Fourth Ave., New York.

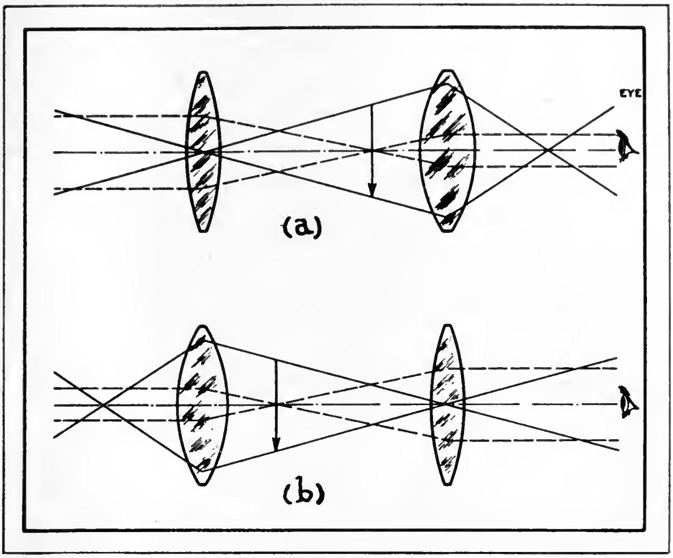


Fig. 1.

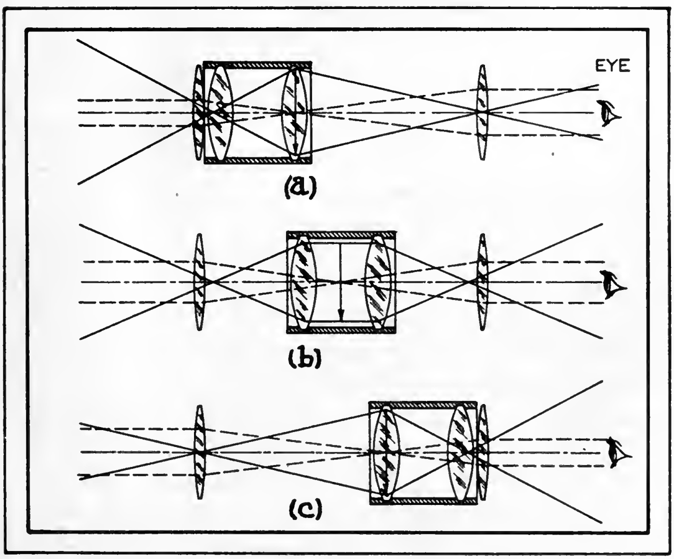


Fig. 2.

large parallactic error. This is particularly true when the eye is displaced. One other type of view-finder having a turrethead might be mentioned here. Its evident disadvantage lies in the limitations placed upon it by the number of optical elements in its turrethead.

The vari-focal system of the new positive view-finder is based, of course, on the principle of the astronomical telescope. The finder adds to this principle certain other features which give it decided advantages. In the astronomical telescope, magnification is determined by the ratio of the focal length of the front lens combination to the focal length of the rear lens combination.

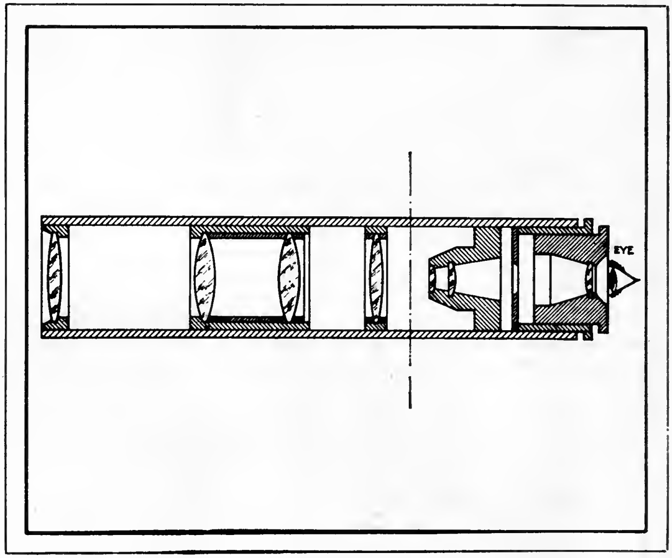


Fig. 3.

Thus, a long focus front lens combined with a short focus rear lens gives us magnification. Fig. 1(a) illustrates this clearly. Conversely, a short focus front lens coupled with a long focus rear lens brings about reduction, as seen in Fig. 1(b).

The new positive view-finder uses a front lens and a rear lens of approximately equal focal length. The front and rear lenses do not move and are known as "stationary lenses." The variation is obtained by 2 lenses of shorter focal length mounted in a barrel within the view-finder housing between the 2 stationary lenses. These 2 shorter focus or "variator lenses" can be moved forward and backward from the front stationary lens to the rear lens. The movable barrel in which they are mounted is called the "variator."

This is how the variator operates: The stationary, and variator lenses are computed in such a way that when the variator is in the extreme front position, the combined power of the stationary front lens and the *first* variator lens is such that the inverted real image produced by them falls on the *second* variator lens. Fig. 2(a) shows this. Thus the second variator lens acts as a field lens in this position and does not participate in the forming of the image. So far, the vari-focal system acts as a telescope that has a short focus objective and a longer focus rear lens, producing a reduced image covering a wide-field angle, as with a wide-angle lens.

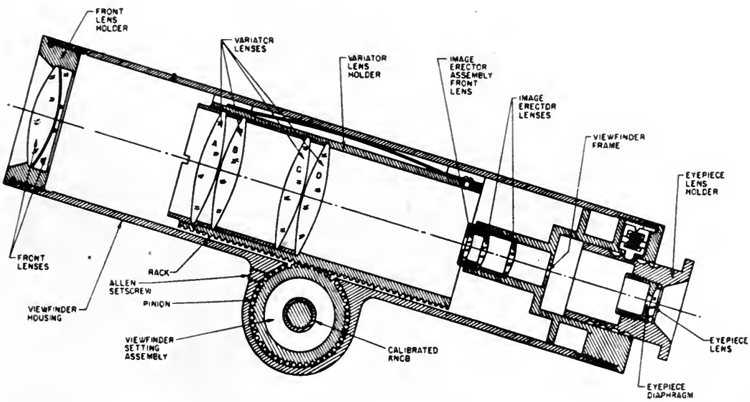


FIG. 4.

Magnification is produced as the variator barrel is moved toward the rear stationary lens. What happens here, of course, is that the combined focal length of the front stationary lens and the front variator lens increases because the spacing between these 2 lenses becomes wider. Simultaneously the rear variator lens begins to combine its power with that of the rear stationary lens. Fig. 2(b) shows what takes place here. By moving the variator barrel, the focal length of the combined front stationary lens and front variator lens becomes longer, while the focal length of the combined rear variator lens and rear stationary lens shortens as the spacing between them decreases. Thus, the change from a reduced image to an enlarged one occurs when the combined focal length of the front optical elements becomes greater than the combined focal length of the rear elements.

The largest magnification is produced by the vari-focal system when, in the extreme rear position, the image formed by the front stationary lens falls into the front variator lens. In this position the vari-focal system covers only a small field angle and therefore corresponds to a telephoto lens. (See Fig. 2(c) .)

Two serious disadvantages to the vari-focal system as a complete view-finder when used alone have been overcome in the new positive

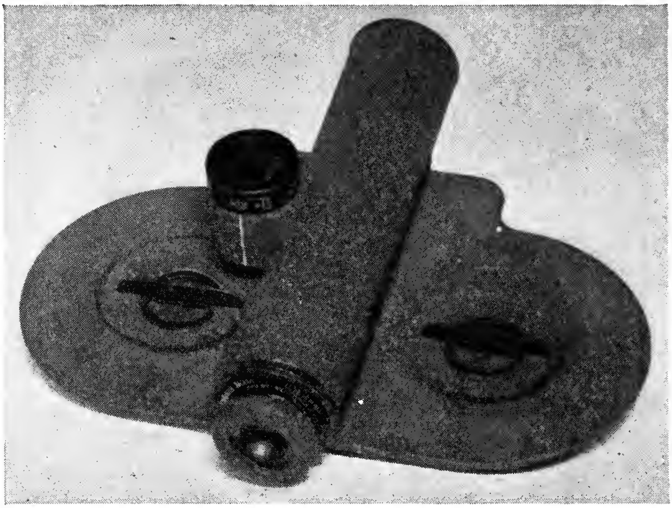


FIG. 5.

view-finder. It has been noted, of course, that the objective lens combination produces an *inverted* image, an objectionable feature in a view-finder. A more serious defect of the "variator" system lies in the fact that the image moves in opposite direction to the movement of the "variator" barrel from the inside of the rear "variator lens" to the inside of the front "variator lens." So in spite of it being a real image, it cannot be framed.

Combined with the vari-focal system to overcome these disadvantages is an *erector* system. Fig. 3 is a diagrammatic representation of the view-finder. The dotted line separates the vari-focal mechanism from the erector system. This erector system acts practically as a second telescope which collimates the image through the combination of the variator and stationary lenses.

This new image is not only upright as the name erector system implies, but it remains practically stationary within the erector system, because the optical elements of this second telescope do not change. Therefore, a frame can be placed at the image point which corresponds to the size of the film frame and which shows accurately the image which will be produced by the corresponding camera lens.

A cross section through the actual view-finder, illustrated in Fig. 4, shows how the optical elements are arranged. How the new positive view-finder appears mounted on the door of the Bell and Howell Eyemo camera is shown in Fig. 5.

SOCIETY ANNOUNCEMENTS

MEMBERS LOST SERVING THEIR COUNTRY

The Society desires to compile a list of members who gave their lives while serving with the Armed Forces of their country. Such a list will include members abroad who served with Allied military forces as well as those in the services of the United States.

The general office of the Society is not always advised of deceased members, and it will be appreciated if readers of the JOURNAL will forward the name of any member known to them to have been a war casualty. Please include with names submitted the approximate date, place, and any other information available.

Your cooperation will assist the general office in obtaining a complete and accurate list for the records of the Society.

EMPLOYMENT SERVICE

POSITIONS OPEN

Designer and engineer experienced in optics, lighting, and microphotography, capable of designing microfilm reading equipment and products related to microfilm industry. Reply to Microstat Corporation, 18 West 48th St., New York 19, N.Y.

Design engineer, experienced in mechanics and optics of motion picture cameras, projectors, and film scanning. Give details. Reply to Mr. John H. Martin, Columbia Broadcasting System, Inc., 485 Madison Ave., New York 22, N.Y.

POSITIONS WANTED

Sound recording engineer, 16- or 35-mm equipment, studio or location work, single or double system. Free to travel. For details write J. J. K., 354 Ninth Ave., New York 1, N.Y.

Honorably discharged veteran with 15 years' experience in all phases of motion picture production, including film editing, directing, producing. For details write F. A., 30-71 34th St., Long Island City 3, N.Y. Telephone AStoria 8-0714.

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

Chief Engineer of motion picture camera manufacturer now available. Special training in optics, electricity, electronics, mechanics. Experienced in all phases of manufacture of cameras, projectors, and accessories. Prefer West Coast, but not essential. Write Robert Winkler, 119 West 78th St., New York, N. Y.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

AUTHOR AND CLASSIFIED

INDEXES

VOLUME 45

JULY-DECEMBER, 1945

AUTHOR INDEX, VOLUME 45

JULY-DECEMBER, 1945

CLASSIFIED INDEX, VOLUME 45

JULY-DECEMBER, 1945