7478

JOURNAL OF THE SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

SMPTE

THIS ISSUE IN TWO PARTS

Part I, December 1953 Journal • Part II, Index to Vol. 61

VOLUME 61

July — December 1953

SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

40 West 40th St., New York 18

CONTENTS — Journal

Society of Motion Picture and Television Engineers

Volume 61 : July — December 1953

Listed below are only the papers and major reports from the six issues. See the Volume Index for those items which generally appear on the last few pages of each issue: Standards, Society announcements (awards, Board meetings, committee reports, conventions, engineering activities, membership, nominations, section activities), book reviews, current literature, letters to the Editor, new products and obituaries.

July

August — Part I

August — Part II

September — Part I

September — Part II

October

November

December

Correction of Frequency-Response Variations Caused by Magnetic-Head Wear

By KURT SINGER and MICHAEL RETTINGER

Wear on a magnetic-recording head reduces the front-gap pole-face depth and thereby produces an increase of the gap reluctance. This in turn produces a higher effective bias flux which has an erase action and thus tends to attenuate the high frequencies as they are being recorded on the recording medium. It is the purpose of the paper to present these performance variations as a function of the lowered inductance associated with head wear and to show how, simply through a correction of bias current, proper performance can be restored.

It has been noticed in the past that wear on a magnetic-recording head results in a decrease of high-frequency response of the overall magnetic recording-reproducing system and also in a change of head sensitivity. The information and data contained in this article explain the reasons for the change in frequency characteristic and offer a simple expedient for correcting the losses and thereby extending the useful life of magnetic heads.

While the benefits of a high-frequency bias current employed in magnetic recordings have been described in numerous publications, it is not frequently noted that the use of too much bias entails the loss of recorded high frequencies. This is due to an erase action produced by the bias flux at the front gap of the recording head. As the recording medium moves past the gap, it is subjected to a rapidly alternating magnetic field, which tends to restore the medium to its neutral or virginal state, wherein the magnetic dipoles are oriented heterogeneously. This effect is more pronounced for the high frequencies than for the lows and appears to be associated with the recorded wavelength.

Wear on a magnetic-recording head reduces the front-gap pole-face depth and thereby produces an increase of the gap reluctance. This in turn produces a higher effective bias flux which has, as noted above, an erase action and thus tends to attenuate the high frequencies as they are being recorded on the recording medium. It should be noted that this higher front-gap reluctance is due only to the decrease in front-gap pole-face depth and not to any widening of the gap, which with our type of

Presented on May 1, 1953, at the Society's Convention at Los Angeles by Kurt Singer and Michael Rettinger, Radio Corporation of America, RCA Victor Div., 1560 N. Vine St., Hollywood 28, Calif.
(This paper was received April 22, 1953.)

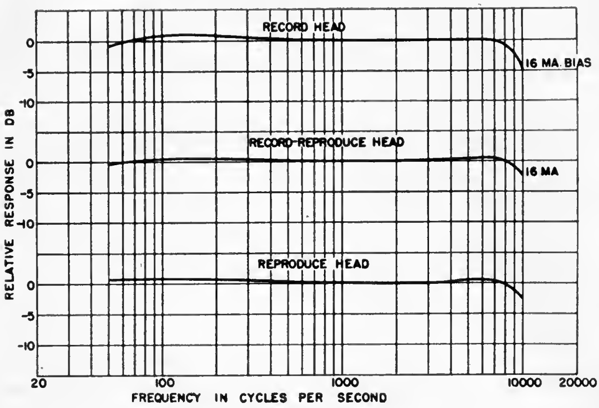


Fig. 1. Frequency characteristic at initial bias current head inductance 4.9 mh, 45 fpm.

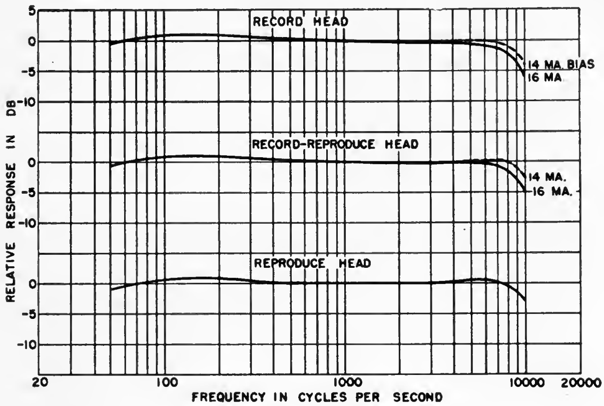


Fig. 2. Frequency characteristic vs. initial and optimum bias current head inductance 4.5 mh, 45 fpm.

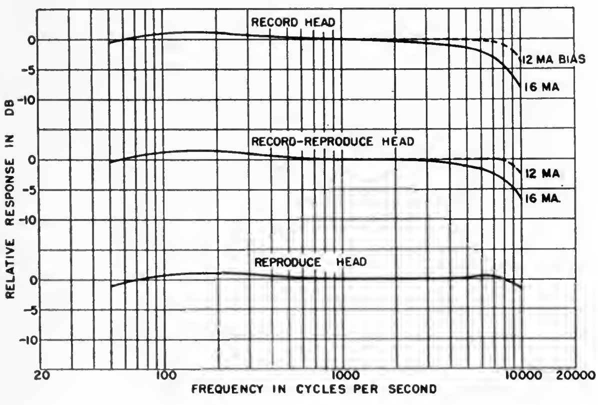


Fig. 3. Frequency characteristic vs. initial and optimum bias current head inductance 4.2 mh, 45 fpm.

magnetic-head construction remains constant.

To permit a ready evaluation of the test results, it is desirable to describe the method of testing. First, a frequency recording was made with an MI-10795-1 Head hereinafter called the test head. The film speed was 45 fpm and the initial bias current 16 ma at 68 kc. The recording was then reproduced on a similar head and the properly equalized output from it was taken as an indication of the performance of the test head as a record head. Next, the recording was reproduced on the test head and the output from it was taken as an indication of the performance of the test head as a combination record-reproduce head. A frequency film which had been made previously was then reproduced on the test head and the output from it was considered an indication of the performance of the test head as a reproduce head. The three frequency characteristics thus obtained are shown in Fig. 1. The top, center and bottom curves show the initial test-head performance as a record, record-reproduce and reproduce head, respectively.

The test head was then removed from the recorder, lapped until its inductance was lowered by 0.4 mh, that is, reduced from an initial 4.9 mh to 4.5 mh. The entire test was then repeated, thereby obtaining new performance data on part of the test head as a record, record-reproduce and as a reproduce head. It was noticed that the change in frequency response (loss of highs) resulting from the lowered inductance was greater when the head was used as a record head than when it was used as a reproduce head. To restore the frequency response of the record head to normal, the bias current had to be reduced to 14 ma. The frequency characteristics obtained from the test head with its inductance reduced to 4.5 mh are shown in Fig. 2. The upper and center curves show head performance as a record and record-reproduce head with the initial bias of 16 ma, and the reduced bias of 14 ma (dashed line). The test head was then removed again from its mount, lapped so that its inductance was lowered again by a certain amount, in this case from 4.5 to 4.2 mh, and the tests were repeated. The frequency characteristics obtained from this series of tests are shown in Fig. 3. Again it should be noted that the reduction of bias current to 12 ma for this head inductance of 4.2 mh restored head performance to normal. Figures 4, 5 and 6 depict the head performance for inductances of 3.85, 3.5 and 3.1 mh. These curves also show the change in bias current required to regain proper frequency characteristics.

Figure 7 shows the gradual loss in high frequencies as the recording-head inductance drops from 4.9 to 3.1 mh at a constant bias current of 16 ma.

When the region of maximum sensitivity bias of the record head over the range of inductances from 4.9 to 3.1 mh was investigated, it was noticed that the initial bias current of 16 ma and the reduced optimal bias currents in all cases represented bias currents corresponding to a value either equal to or slightly lower than maximum sensitivity bias. However, this statement should not be construed to mean that it is only necessary to adjust the bias current to maximum sensitivity bias to recover the lost high frequencies. This procedure would only result in an approximately normal performance. In order to compensate for head wear accurately, it is necessary to reduce the bias current experimentally to a value which will produce the initial frequency characteristic.

During these tests it was also noticed that a sensitivity change of the test head took place. The sensitivity variations are shown in Fig. 8. Zero sensitivity of the test head as a record head corresponds to the sensitivity of the head with its full inductance of 4.9 mh operating

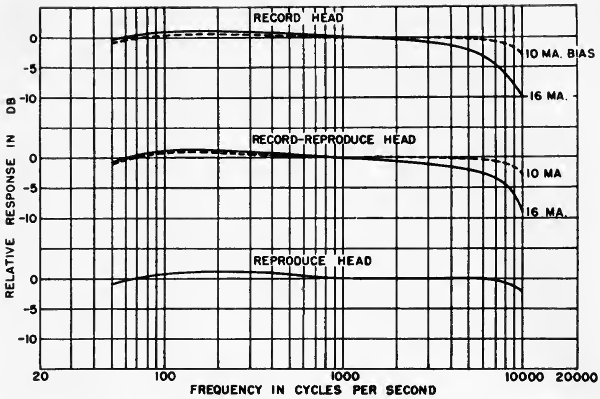


Fig. 4. Frequency characteristic vs. initial and optimum bias current head inductance 3.85 mh, 45 fpm.

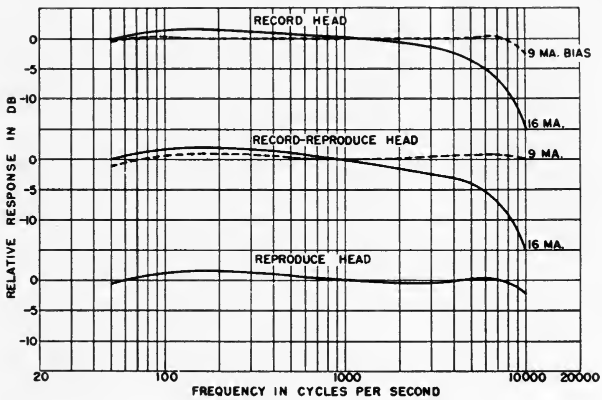


Fig. 5. Frequency characteristic vs. initial and optimum bias current head inductance 3.5 mh, 45 fpm.

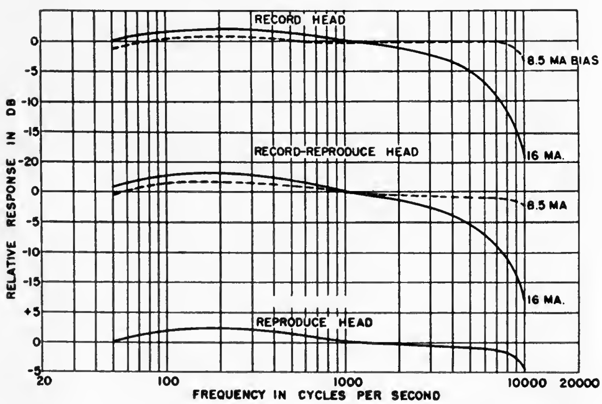


Fig. 6. Frequency characteristic vs. initial and optimum bias current head inductance 3.1 mh, 45 fpm.

Fig. 7. Frequency response vs. inductance of recording head measured at constant bias of 16 ma. 45 fpm.

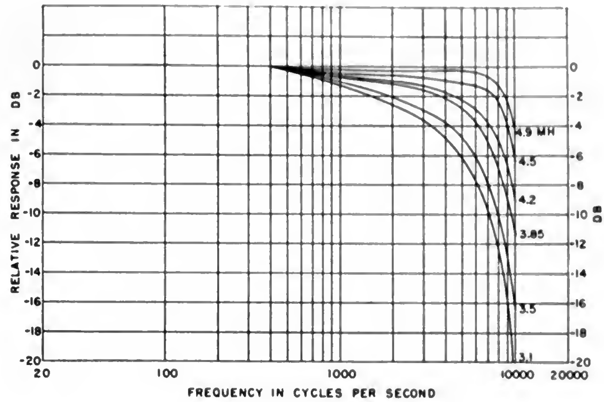


Fig. 8. Head inductance vs. sensitivity change, 45 fpm, 400 cycles.

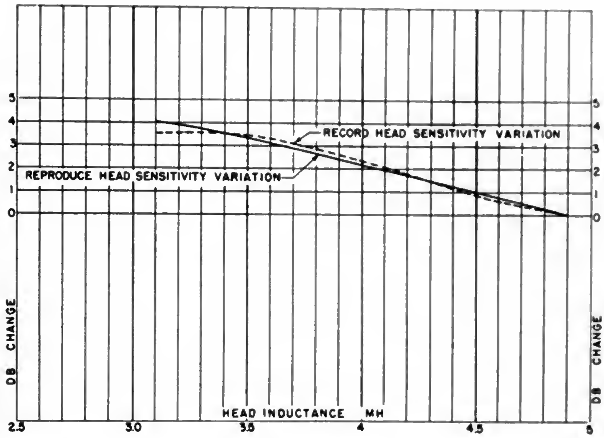
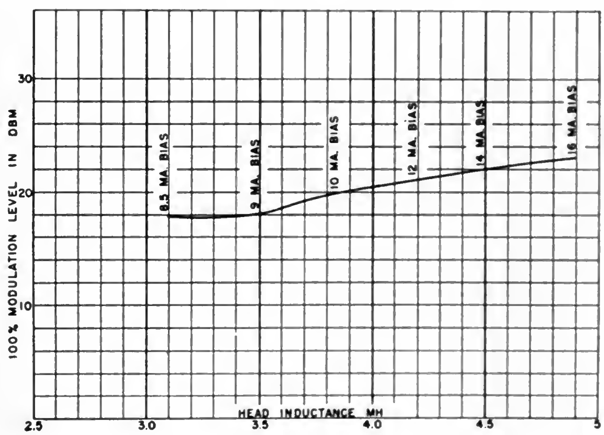


Fig. 9. Head inductance vs. optimum bias current vs. 100% modulation level, 400 cycles, 45 fpm.



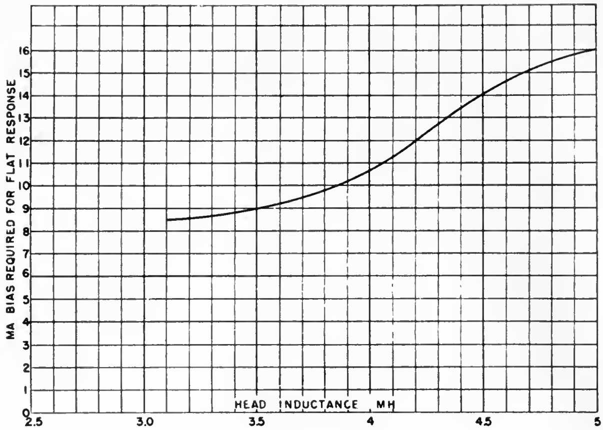


Fig. 10. Head inductance vs. optimum bias current, 45 fpm.

at a bias current of 16 ma. It should be noted that as the head inductance is decreased, and the head sensitivity increased, it is necessary in order to obtain 100% modulation (approximately 2.5% distortion at 400 cycles), that the signal input to the head (signal current) be reduced by the amount shown on this curve. In exploring the performance of the test head as a reproduce head, zero sensitivity was assumed as the sensitivity of the head with an inductance of 4.9 mh. As the head inductance was lowered, the output from the head increased by the amount shown on this curve.

Figure 9 shows the change in the 100% modulation level that was noted as the head inductance was decreased and the bias current readjusted for satisfactory high-frequency performance.

Figure 10 has been included to show approximate values of optimum bias currents which can be used in an initial attempt of correcting for high-frequency loss by the record head when the head inductance has been reduced due to head wear. It must be understood that this curve can only be offered as an approximation toward the desired optimal bias current. Minor deviations from it may exist in individual cases.

All the tests described above have been made at a film speed of 45 fpm. The attenuation of recorded high frequencies due to magnetic-head wear at other film speeds will have the same trend, although it does not necessarily follow that the same patterns, obtained with a 45-fpm film speed, will result. However, practice has shown that in all cases it has been possible to regain lost high frequencies through a reduction of bias current.

We would like to inject a note of caution, namely, that each change in bias current necessitates the re-establishment of the 100% modulation recording level to avoid overloads and resultant increase in distortion.

Discussion

Anon: I would like to know if you're getting any variation in the signal-to-noise ratio out of your tape with this output variation, a decrease of high-frequency bias and concurrently of modulation level.

Mr. Singer: No, we have not noticed any deterioration of signal-to-noise ratio. The signal-to-noise ratio essentially stays the same, as with the initial bias and the initial modulation level.

Anon: Because, of course, the maximum level that you get from your tape must decrease definitely. Then, suppose you are recording 100% as established by 2.5% distortion. You recorded with a normal head and normal conditions — 16 ma and whatever db level you're using. Then you record a second tape at a lower general level with another head. If you produce these two tapes, both recorded at 100%, you must evidently get a lower level out of the second tape than you got from the first tape.

Mr. Singer: No, we do not obtain any lower level from the second tape, because the magnetization that is inherent in the film will be the same. If they're going to work at the same bias sensitivity, they will also have the same voice sensitivity. As the head wears down and the gap reluctance increases, its flux fringing which increases is applicable to the bias flux as well as to the modulation flux. So, essentially, we get the same output. I don't think we noticed more than maybe a db output variation over the entire range of head inductances and bias correction.

George Lewin (Signal Corps Pictorial Center): Can you give us a rough idea of how many feet of film you run through before you reach the extreme values of head wear that you indicate here?

Mr. Singer: Perhaps Mr. Rettinger is in a better position to answer this question?

Mr. Rettinger: The head was lapped down by hand on a 600 grit silica carbide paper.

Mr. Lewin: Yes, I understand that. But you must have some idea as to how much equivalent footage is represented.

Mr. Rettinger: In general, you mean?

Mr. Lewin: Yes, that's right.

Mr. Rettinger: It depends on a number of factors such as film speed, type of tape, film tension, etc. On a triple-track head, in one of the studios for instance, we were able to pass over 3 million feet of film before the head inductances had lowered to 3 mh.

Mr. Lewin: Which is the extreme amount that you showed here. Three million feet of film, you say, is roughly the equivalent of the maximum amount of wear that you showed?

Mr. Rettinger: That's right.

Anon: What sort of life should we expect, roughly, from the reproducing heads in terms of feet of film that run over them and also near the end of that life, what is to be expected with regard to the output level and the change in frequency response, if any?

Mr. Rettinger: As I just said, one may expect at least 3 million feet of film to pass over the head before its inductance has dropped to 3 mh. That is, under the condition that we call the tight-loop system. Where there's less film tension on a head, the life of the head may be extended. How long? I don't have that information available. With regard to sensitivity variation, I think that was indicated on the slides. There would be approximately a 3-db gain in head sensitivity when the inductance has been lowered from 5 to 3 mh.

Anon: Would Mr. Rettinger continue and indicate the change in the frequency response near the end of reproducer head life?

Mr. Rettinger: That was shown on the curve. There's very little change in the frequency response of the reproduce head down to, let us say, 3 mh. After that when the gap begins to open up, naturally there will be a rapid falling off of high-frequency response.

Anon: Is what you said applicable in general to most any make of reproduce head that we might find in theaters in the near future, as far as we know?

Mr. Rettinger: Not necessarily. It depends on the way the head is constructed. If the front gap is built so that it remains of constant length as the head wears down, I would expect very little change in frequency response. But if the head is built so that the front gap will lengthen as the head is worn down, then, naturally, there will be a loss of high frequency. Our heads are built so that the gap length remains constant.

16mm Motion-Picture Theater Installations Aboard Naval Vessels

By PHILIP M. COWETT

The Navy's shipboard motion-picture installations, involving special location problems calling for equipment of great flexibility, and acoustic problems complicated by high noise levels, are briefly described.

We have presented to this Society at various times the Navy story regarding the problems incurred in the procurement of film of adequate quality to meet the needs aboard ship. We have never, however, described before this Society the theater installations utilizing 16mm equipment aboard Navy vessels located throughout the world. These installations generally break down into categories of ships such as destroyers, aircraft carriers, battleships — each with its own specific problem. The purpose of this paper is to describe some of these installations and set forth the Navy's program at this time with regard to 16mm film and its professional use as a serious entertainment medium.

Following the last world war, a survey was made of the various overseas shore-based activities and ships to determine whether they desired to continue with the use of 35mm film and equipment or convert to the equivalent in 16mm with its obvious advantages with regard to transportation, handling, lack of fire hazard and so forth. This resulted in the report from the various polled activities that 16mm would be very desirable from the standpoint of naval use if equipment could be procured that would match the 35mm equipment characteristics.

Obtaining adequate equipment became a separate project which resulted in the development of two projectors meeting identical performance requisites. As to the equipments themselves, they have been described in the paper presented before the Society by Orr and Cowett in 1951.[1] Very little more need be added as to their performance.

As may be realized, a naval vessel is designed and constructed for one purpose — and that purpose, unfortunately for the motion-picture viewer, is not the showing of motion pictures. Since nothing is allowed to take place aboard ship which will interfere with the prime mission of the ship, our activities must accommodate themselves in any manner possible. One thing, however, becomes readily apparent, and that is the absence

Presented on April 22, 1952, at the Society's Convention at Chicago by Philip M. Cowett, Dept. of the Navy, Bureau of Ships, Washington 25, D.C.
(This paper was first received March 26, 1952, and in revised form on June 26, 1953.)

of acoustic treatment in any part of the ship. Therefore, there is really no best location for the evening show.

The first, or simplest type of installation, is that to be found aboard a destroyer or lesser craft. In this case the particular vessel is assigned a standard portable equipment, comprising a projector, 20-w amplifier, and 25-w loudspeaker. Individual ships sometimes manufacture portable bases for themselves, but none are provided as an allowance item. Figure 1 shows a single equipment (except for the loudspeaker) on board an LST.

Since the distances of throw are varied and limited, and the availability of permanent locations for the projection of film is nonexistent, it is essential that the equipment be easily portable. In good weather the shows are generally projected topside under the stars where high ambient noises are the rule. The projector, mounted on a steel stand, which is generally lashed to the deck, is set up in the most suitable location for the particular vessel, between 50 and 175 ft from the screen which measures approximately 9 ft 6 in. in width. With this vibrating platform as a projection booth preparations for the evening show go on. Vibration is due to the fact that on many types of vessels one of the two propeller shafts of the ship passes almost directly beneath the point where the projector is set up. Interconnection between the various units is established and the show is ready to start.

Of course the portable direct radiator type loudspeaker is mounted as high as possible close to the screen in order that adequate sound coverage may be obtained. There is not much in the way of height around the screen except the screen frame itself, which may or may not be able to support extra weight, since the screen acts as a sail and additional weight could cause it to buckle completely. When the ship is traveling by itself, with no particular time schedule for arriving at any one particular port, or where a ship can make up lost time, the Commanding Officer will normally reduce the speed of the ship to fifteen knots or less or even change course for the duration of the show. This permits a properly lashed down screen to remain in place without too much flapping.

Fig. 1. Portable projector and amplifier.

It has been stated that two projection equipments had been developed—one a 20-w unit and the other a 5-w system.

The 5-w unit is aboard ship for training purposes, since a vessel of destroyer size is not large enough to warrant two projection equipments for entertainment purposes alone. There is, however, a definite advantage in the use of even one 16mm equipment as compared with the 35mm, since we have to change reels only once every 45 or 50 min, whereas with 35mm, reel changing is much more frequent.

The 5-w equipment is designed with changeover facilities as is the 20-w equipment previously mentioned. Since both the 5-w and 20-w equipments have identical characteristics[2] and identical inputs and outputs including plugs and receptacles, the two can be interconnected in such a manner that a dual show may be given, without stopping the projectors for changing reels, and thereby accomplishing instantaneous changeover in the same manner as do professional 35mm equipments. In this instance the outputs of both projectors feed into the 20-w amplifier, and that 20-w amplifier provides exciter supply for both the 5-w and 20-w projection equipments, the 5-w amplifier being isolated.

Aboard larger vessels, such as a battleship or cruiser, a booth installation is involved. As in the previous instance, the high ambient noise still governs, and the same obstacles exist with regard to securing satisfactory sound distribution topside. Cross winds, engine-room blower noises, noise of the ship underway—all act to hinder the intelligibility of sound to a maximum extent. Of course, the effects of the moon on the picture are also noticeable.

Figure 2 shows a typical shipboard booth installation. The booth is mounted generally just abaft the main mast structure. The screen is located topside at the fantail, or stern of the vessel, and in some cases the distance between the only possible location of the projection booth and the only possible location of the screen is in excess of 200 ft. This installation consists of the following components: two projectors operating as a dual system mounted on specially designed projector stands, which include tilt plates, as in 35mm equipments, and mounting places below the projectors for the amplifiers. In addition a monitor loudspeaker, record player, film stowage space, rewind facilities, etc., are also available.

Changeover facilities are provided as in the installation previously described. The two standard Navy 20-w amplifiers are bridged at the front ends through telephone-type jacks. This allows a supply of an effective 40 w of power to the loudspeaker system located below on the main deck. Figure 3 shows the circuits involved in a cruiser installation.

Since the theater areas in ships of this type must be relatively long, as compared to their widths, and because of the various cross winds and miscellaneous noises encountered, it was necessary that a loudspeaker installation be designed especially for this type of ship. There is permanent ship's wiring between the projection booth and the loudspeakers themselves. The loudspeaker installation consists of two horns, or trumpet-type loudspeakers, mounted on the topmost corner sections of the husky screen frame. These horns are tilted to cover approximately the rear portion of the audience. They are parallel connected to one of the 20-w amplifiers in the booth which independently controls the volume and tone control characteristics of the sound from these particular loudspeakers. Portable-type direct radiator loudspeakers, previously mentioned, are mounted about halfway up on either side of the screen frame. These are tilted in the same manner as the horns; however, they cover only the front portion of the audience. They too are separately controlled by their own individual amplifier. The loudspeaker installation can be seen in Fig. 4. With this type of system the Navy endeavors to provide good quality sound, or as good sound as we can achieve under the particular topside conditions.

When the show is over the four loud-

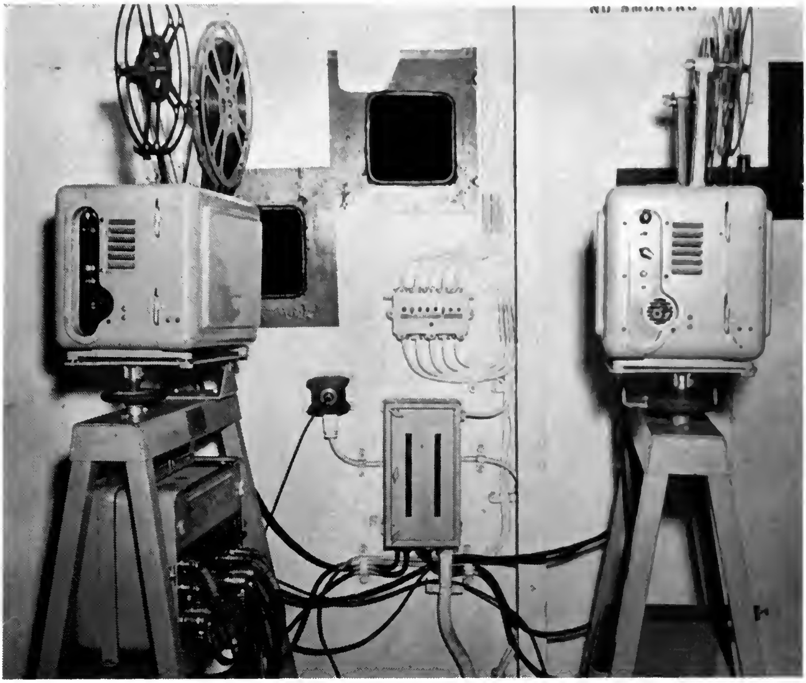


Fig. 2. 16mm shipboard booth installation (*Official Photograph*, **U.S. Navy**).

speakers and the screen with frame are completely dismantled and stowed away in assigned spaces until the following evening. During bad weather, projectors used generally for training purposes, the 5-w unit previously mentioned, or even the 20-w booth equipment can be taken into the wardroom, the crew's mess, or any other interior space and a reasonably good show given.

Projection below deck involves problems of steel bulkheads, decks, overheads, and so forth, which may result in some reverberation. The size of the audience is depended upon to deaden the sound. During inside shows dual operation of the projection equipments is not usually feasible in view of the fact that spaces are too small to hold the entire audience at one time. Therefore, shows are held simultaneously in several different compartments. Each show cannot start at the same time since reels must be passed from one projection area to the other.

A third type of installation would be that on an aircraft carrier, where extremely bad acoustical conditions result in a completely different approach to sound problems. The show, first of all, is presented in one of the hangar areas, normally used for the stowage and repair of aircraft. In some ships such an area is approximately 100 ft in width, 180 ft in length and 18 ft in height. The booth is mounted just below the overhead at one end of the area and projection is toward one of the hangar bay doors on which an 18-ft lace and grommet screen is mounted. A typical motion-picture hangar is shown in Fig. 5.

Projection distances of approximately 170 ft are average in our largest carriers. The projection booth is about the same as that on a battleship or cruiser — about

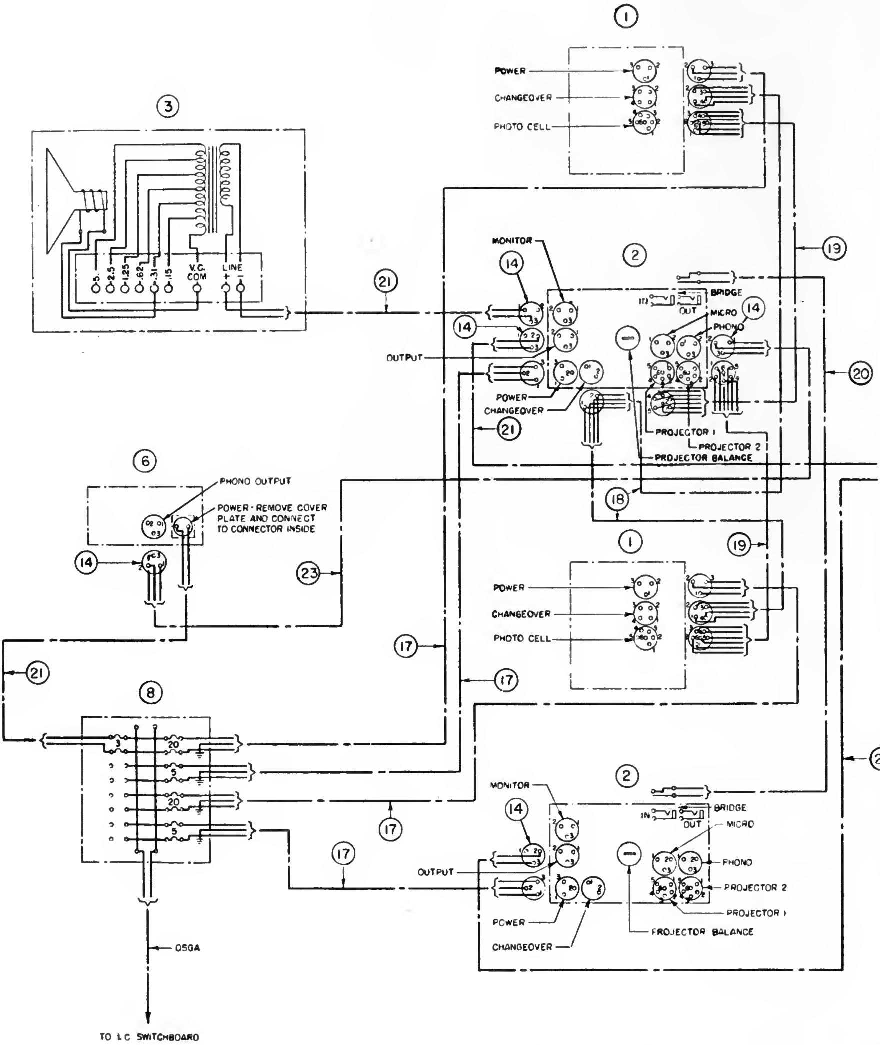
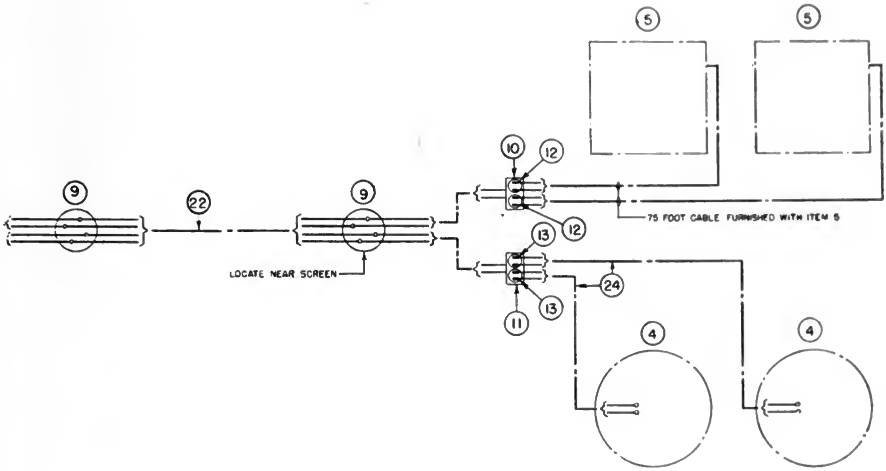


Fig. 3. Cruiser installation electrical wiring layout.



List of Material—Quantities for One Ship

Item No.	*Name*	*Qty.*
1	Projector	2
2	Amplifier	2
3	Loudspeaker, monitor	1
4	Loudspeaker, horn type	2
5	Loudspeaker	2
6	Sound reproducer	1
7	Projector mounting base	2
8	Distribution box	1
9	Branch box	2
10	Receptacle, double, W.T.	1
11	Jack box, W.T., telephone	1
12	Plug, receptacle, SBM	2
13	Plug, telephone	2
14	Plug, three connection	5
15	Blkhd. mtg. bracket for sound reprod.	1
16	Studs for mtg. item nos. 3 and 15	8
17	Power cable assembly	4
18	Changeover cable assembly	1
19	Photoelect. cell cable assembly	2
20	Amplifier bridging cable assembly	1
21	TTHFWA $1\frac{1}{2}$ cable, lengths as required	4
22	TTHFWA 3 cable, length as required	1
23	Cable, shielded, 2 cond., length as required	1
24	Cable, DCOP-2, length 75 ft	2
25	Mtg. bracket for type IC/QDM loudspeaker	2

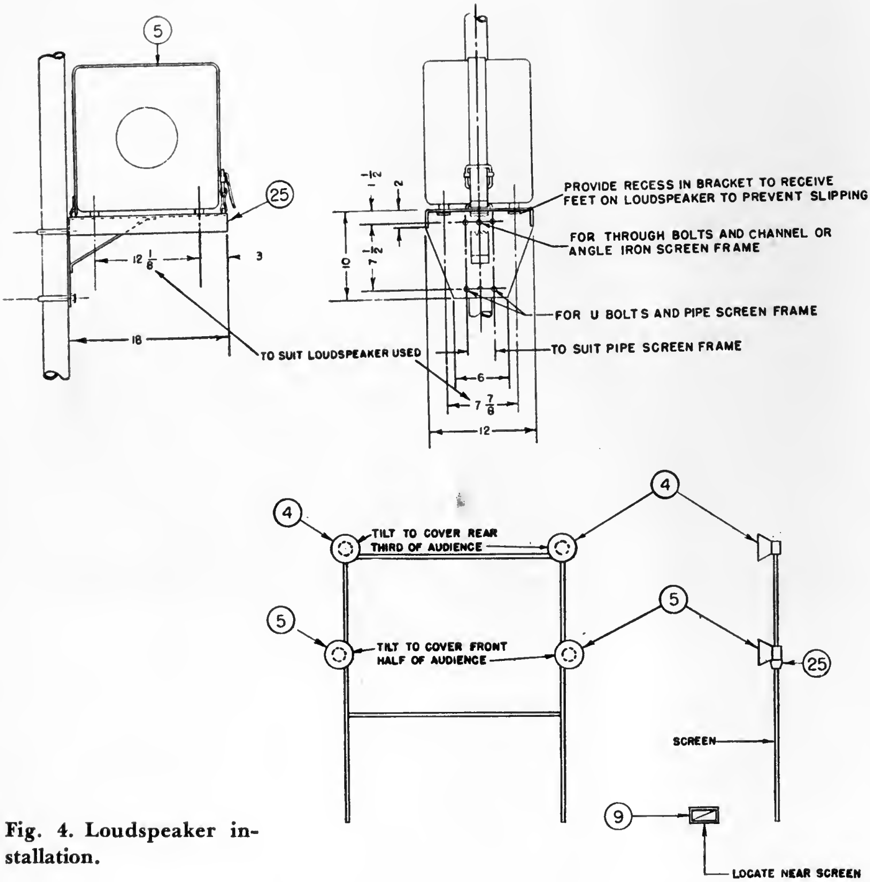


Fig. 4. Loudspeaker installation.

8 ft wide by 10 ft deep by 7 ft high. It contains a rewind table, a little stowage space, record player, and so forth.

The loudspeaker system is, however, completely different from any of the other systems used. Instead of the portable loudspeakers, a number of 12-in. loudspeakers in one-cubic-foot enclosures are mounted to the overhead and spaced approximately on 9-ft centers. Carriers of the *Midway* class have approximately 36 loudspeakers mounted to the overhead (Fig. 6). They are each tilted 20° toward the audience in order to minimize the reverberation which might be caused by the sound bouncing on the steel deck between rows of seats. As can be seen by the loudspeaker arrangement, space is allowed for a passageway in the middle of the audience. All loudspeakers are terminated in a switch control panel in the booth so that the quantity of loudspeakers on at any one time may be adjusted to the size of the audience. Advantage is taken of the sound deadening capacity of the audience and more loudspeakers are therefore connected as the crowd grows. This is a real advantage and allows maximum intelligibility from sound to be obtained. The loudspeaker system is powered by a

Fig. 5. Motion-picture hangar area, U.S.S. Oriskany (CVA34) (*Official Photograph*, **U.S. Navy**).

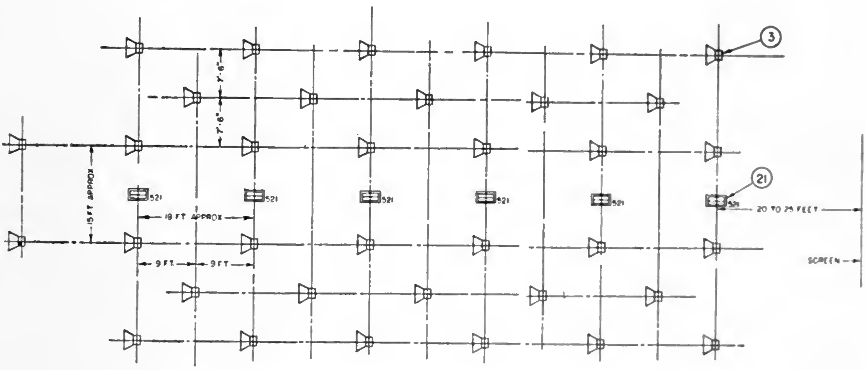


Fig. 6. Overhead loudspeaker layout for U.S.S. Midway class aircraft carrier.

constant voltage of approximately 100 v. Each loudspeaker enclosure contains a transformer which permits the sound output from any one particular loudspeaker to be adjusted depending upon the noise level of the area in which the loudspeaker is located. This, therefore, permits an even sound distribution to reach the entire audience regardless of the noise level surrounding any one person. It is obvious, however, that high ambient noises of 80 to 90 db, and

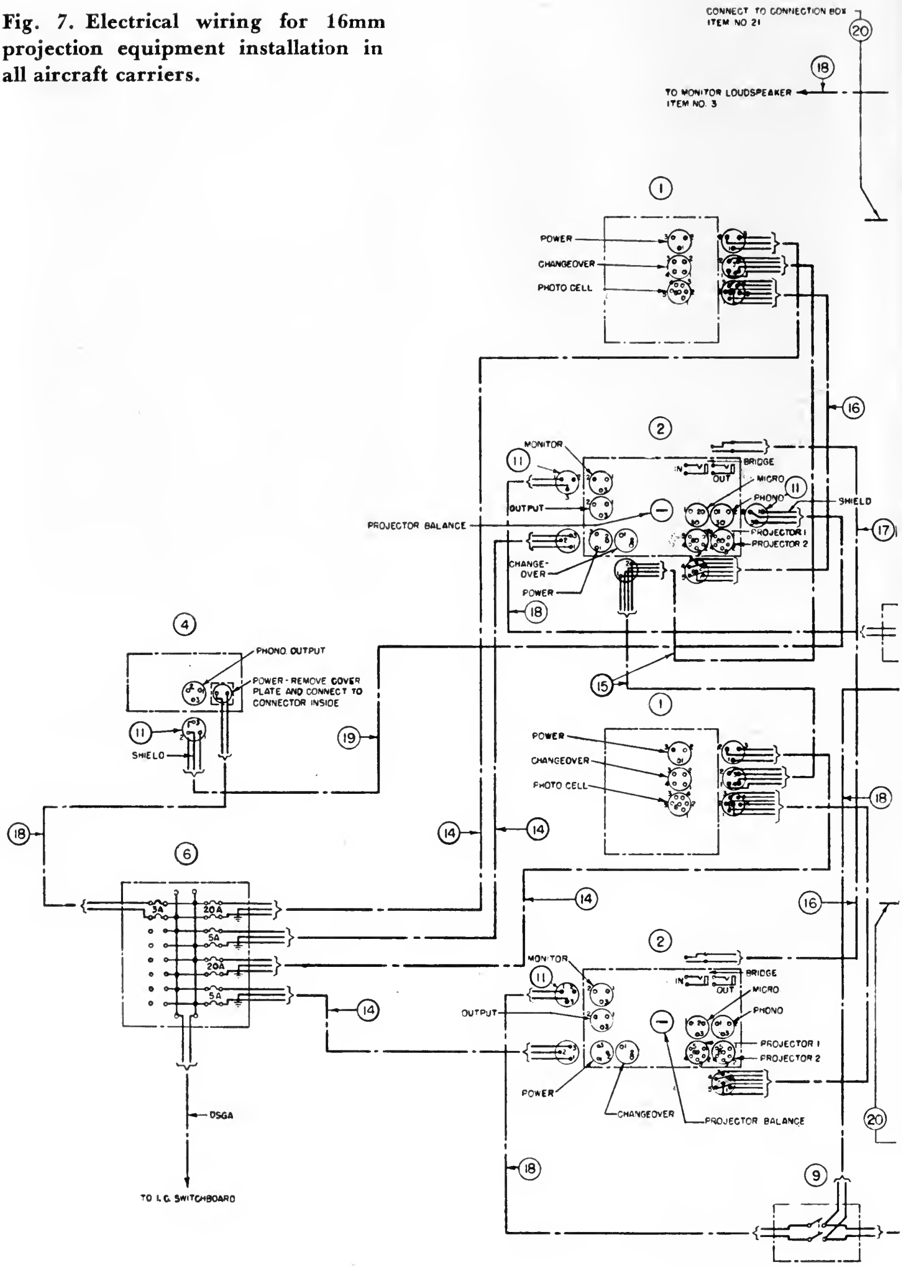
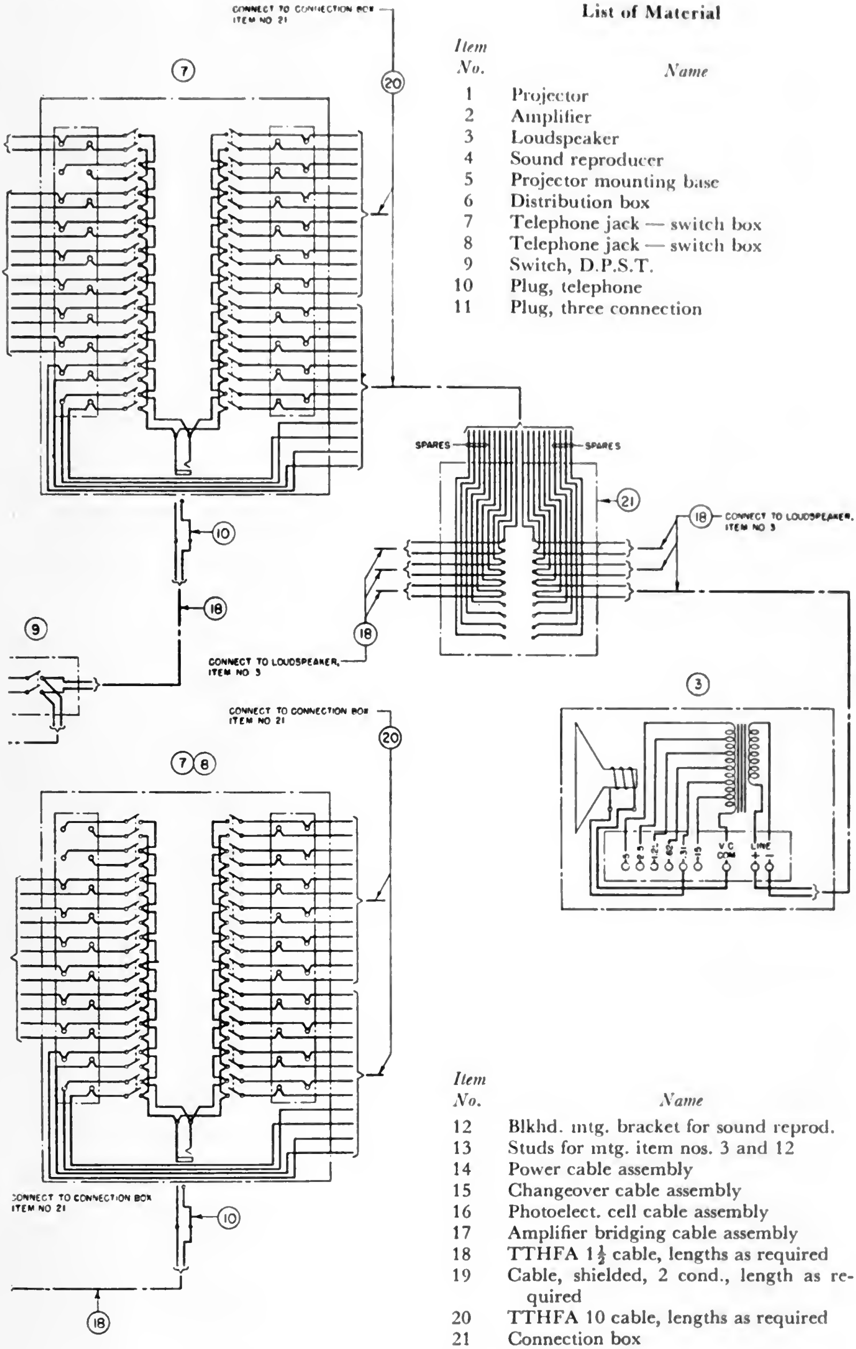


Fig. 7. Electrical wiring for 16mm projection equipment installation in all aircraft carriers.



List of Material

Item No.	Name
1	Projector
2	Amplifier
3	Loudspeaker
4	Sound reproducer
5	Projector mounting base
6	Distribution box
7	Telephone jack — switch box
8	Telephone jack — switch box
9	Switch, D.P.S.T.
10	Plug, telephone
11	Plug, three connection

Item No.	Name
12	Blkhd. mtg. bracket for sound reprod.
13	Studs for mtg. item nos. 3 and 12
14	Power cable assembly
15	Changeover cable assembly
16	Photoelect. cell cable assembly
17	Amplifier bridging cable assembly
18	TTHFA 1½ cable, lengths as required
19	Cable, shielded, 2 cond., length as required
20	TTHFA 10 cable, lengths as required
21	Connection box

reflections and reverberations in the projection area provide serious obstacles to the hearing of highly intelligible sound.

This situation, however, is not unlike that in many industrial areas where loudspeakers are used for public announcing involving coverage over a wide area of enclosed space. Experiments are continually being made to solve the acoustic problems involved. Various types of loudspeakers and loudspeaker systems are being tested in order to procure a more satisfactory final result.

A perfect theater can never result from the efforts made in this direction since the spaces allocated for motion pictures on ships have to fill their primary combat functions first, and can be adapted only secondarily for motion pictures. This, then, means that sound deadening material must be held to a minimum. Inflammable materials are absolutely out, no matter how good their acoustical properties may be.

Only one 20-w amplifier is used to cover the hangar area and to feed the booth monitor loudspeaker. From Fig. 7 it will be seen that both projectors can be fed to one or the other of the amplifiers. Two projectors feeding into one amplifier can be instantaneously shifted to the input of the stand-by amplifier in the event of the failure of the working amplifier. Should other peculiar conditions arise, each projector may feed into its own amplifier with both amplifiers individually feeding into the same overhead loudspeaker system. The switches which accomplish this change are identified by the numeral 9 in the center of the figure. In this manner we have attempted to provide a system of maximum flexibility because the conditions of use are subject to change without notice, depending almost entirely upon the number of persons attending the show; that is to say, of the amount of acoustic or sound absorption material present in the hangar bay area. This, of course, would be in addition to the change of film itself.

References

1. Lowell O. Orr and Philip M. Cowett, "Desirable characteristics of 16mm entertainment film for naval use," *Jour. SMPTE, 58:* 245–258, Mar. 1952.
2. "Tentative recommendations for 16mm review rooms and reproducing equipment," *Jour. SMPTE, 56:* 116–122, Jan. 1951.

A First-Order Theory of Diffuse Reflecting and Transmitting Surfaces

By ARMIN J. HILL

Intensity of light emitted or reflected from a surface in accordance with Lambert's law varies in proportion to the cosine of the angle between the direction of the light beam and the normal to the surface. With many surfaces which do not follow this law, it is possible to approximate the variation of intensity with some power of the cosine. When such an approximation can be made, relatively simple relationships can be obtained for luminance (brightness), emittance and related factors. Use of this approach may take some of the mystery out of such problems as the determination of screen brightness and a study of transmission characteristics of process screens.

LAMBERT'S LAW, which states that the intensity of light emitted from a perfectly diffusing radiator is proportional to the cosine of the angle between the normal to the emitting surface and the direction in which the intensity is measured, provides a simple mathematical basis for treating luminous surfaces which radiate according to this law. Unfortunately, few surfaces are perfect diffusers and serious errors will result if the simple equations derived from Lambert's law are applied to them. Many of the reflecting and transmitting screens used in the motion-picture and television industries are, in fact, quite highly directional, though not enough so that they can be treated according to the laws governing specular reflection or direct transmission.

Considerable literature is available on the theory of radiation transfer and on the processes by which light is diffused and scattered as it traverses various media. Most of this has approached the problem from too fundamental a viewpoint, however, to provide workable equations by means of which "partial diffusion" might be treated. This paper suggests an approach which is almost entirely empirical, based upon experimental tests on transmitting and reflecting screens, disregarding completely the processes by which this transmission or reflection takes place. These processes are therefore treated exactly as they are in applications of Lambert's law. The slight modification of the equations does not prevent, in most cases, an extension of the ideas

Presented on October 9, 1952, at the Society's Convention at Washington, D.C., by Armin J. Hill, Motion Picture Research Council, 1421 North Western Ave., Hollywood 27, Calif.
(This paper was first received on November 3, 1952, and in revised form on May 12, 1953.)

based on this useful law to include directional screens and to treat these screens in the simple manner otherwise only safely applicable to perfect diffusers.

In analyzing the characteristics of translucent screens used for background process projection, it was noticed that the fall-off of intensity with increasing angle from the normal would be closely approximated, not by a cosine curve as for a perfect diffuser, but by using some power of the cosine of the angle. To show how closely this approximation holds, Figs. 1a–d show experimental curves obtained by means of a goniophotometer on experimental screens analyzed by Dr. Herbert Meyer of the Motion Picture Research Council. (Data were taken according to requirements of A.S.T.M. Designation D636–43.) The dashed curves in each set represent suitably selected cosine power curves, with the selected power used as a "shape factor" and symbolized by the letter s. It is immediately apparent that except for very low intensities, the cosine curve matches the experimental curve within a few percent — in fact in most cases within the instrumental error of the goniophotometer. Since most of the errors at very low intensities tend to make the readings too high, actual fit may be even better than that shown by the diagrams.

This comparison was then tried on data for typical reflecting types of surfaces with results as shown in Figs. 2a–d.[1] It will be seen that within angles of interest for most photographic work, the approximations again are good within a few percent. Care must be used, of course, in applying these in such cases as the beaded screen where a considerable portion of the total flux is emitted at large angles, for in such cases relations involving this total flux will be seriously in error. However, the particularly important relations between intensity, luminance and illuminance will hold when only small angles are involved.

In the following formulae, notation follows that employed by Sears.[2]

Definitions:

- F, luminous flux;
- I, luminous intensity or flux per unit solid angle;
- B, luminance (brightness);
- E, illuminance or flux per unit area received at a surface; and
- L, luminous emittance or total flux emitted per unit area.

Defining equations:

$$I = \frac{dF}{d\omega},$$ where ω is solid angle with vertex at source;

$$E = \frac{dF}{dA} = \frac{I_\theta \cos\theta}{r^2},$$ where θ is angle with normal to surface;

$$B = \frac{\Delta I_\theta}{\Delta A \cos\theta};$$ and

$$L = \frac{\Delta F}{\Delta A},$$ F is total emitted flux.

The following equations compare intensity and brightness for a surface which follows Lambert's law, with one which is directional but for which the intensity falls off in proportion to some power s of the cosine of the angle with the normal to the surface.

Lambert Surface	*Directional Diffuser*
$I_\theta = I_o \cos\theta$	$I_\theta = I_o \cos^s\theta$
$B_\theta = B_L$	$B_\theta = B_D \cos^{s-1}\theta$

Here B_L represents the brightness of the Lambert surface, and B_D the normal brightness of the directional surface.

---

[1] Sources for these data were: (a) for sandblasted mirror, James R. Cameron, *Motion Picture Projection*, Cameron Publishing Co., Coral Gables, Fla., 4th ed., p. 199; (b) for others, Ellis W. D'Arcy and Gerhart Lessman (De Vry Corp.), "Objective evaluation of projection screens," presented on April 22, 1952, at the Society's Convention at Chicago.

[2] E. W. Sears, *Principles of Physics, Vol. 3 — Optics*, Addison-Wesley, Cambridge, Mass., 1948, 3d ed., chap. 13.

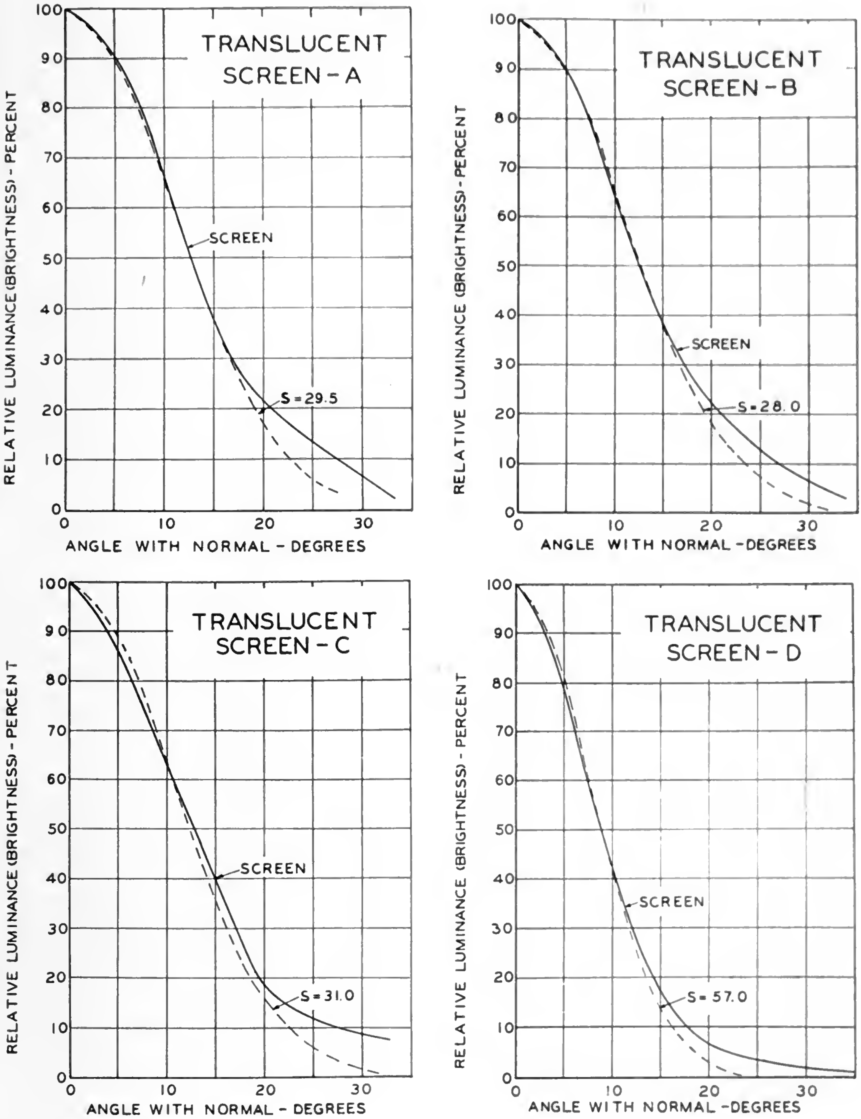


Fig. 1. Approximations of luminance fall-off for experimental translucent screens. Solid curves show experimental data, dashed curves show ratios of $B\theta/B_0$ obtained from the equation $B\theta = B_0 \cos^{s-1}\theta$.

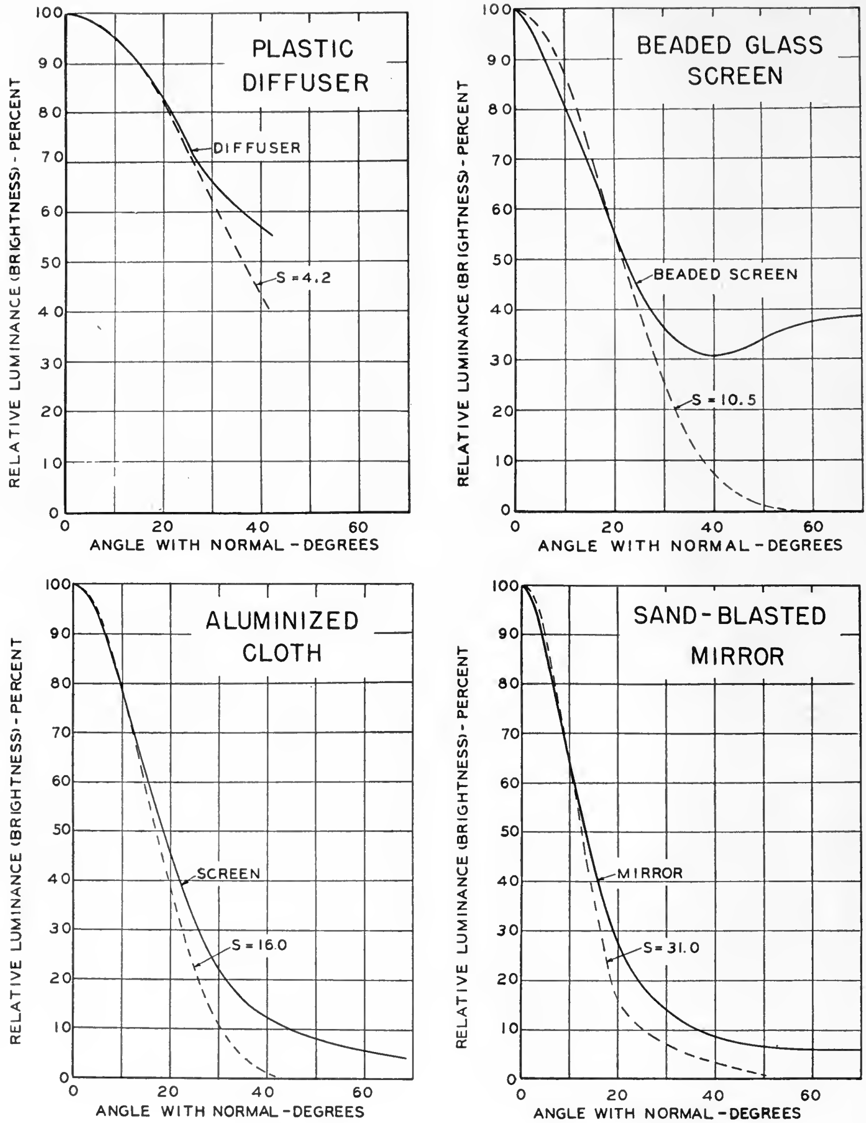


Fig. 2. Approximations of luminance fall-off for typical reflecting screens. Use of solid and dashed lines is the same as for Fig. 1; parts a-d, in the usual order

The *illuminance* or flux received per unit area at a point not on the screen illuminated by a circular area of the screen whose center is at the foot of the perpendicular from the point and whose radius subtends an angle α at the point is found by integration to be:

Lambert Surface

$$E_L = \pi B_L \sin^2 \alpha$$

Directional Diffuser

$$E_D = \frac{2\pi}{s+1} B_D (1 - \cos^{s+1} \alpha)$$

and the *luminous emittance* or total flux emitted by a unit area of the screen surface is:

Lambert Surface	*Directional Diffuser*
$L = \pi B_L$	$L = \frac{2\pi}{s+1} B_D$

If we neglect any differences which may exist in absorption or other screen losses, we can compare maximum normal brightness by assuming that the total luminous emittances are equal, in which case we see that

$$B_D = \frac{s+1}{2} B_L$$

This shows clearly why the "brightness" of a directional screen in footlamberts may often be several times the intensity of the incident radiation in foot-candles.

The "shape factor," s, provides a convenient index to the diffusing characteristics of the screen. For a perfect diffuser, it is of course, unity, while for a nondiffuser (free transmission or specular reflection) it becomes infinite. As shown by the curves in Figs. 1 and 2 it usually takes on values between 1 and 50.

These equations show why meters which actually read illuminance instead of luminance, do not give correct luminance readings for directional screens. For example, a meter such as the G.E. screen-brightness meter, having an admittance half-angle of 15° will read about 8.5% low, while for a screen having s = 10 this will drop to 20.5% below what it should read.

These equations have been found to be useful in predicting size and relative intensities of "hot spots" from data obtained from relatively small screen samples, in correcting transmission data taken by the various methods in current use, and in suggesting designs for suitable instruments for use in measuring various screen characteristics. They should also prove useful in the analysis of screen brightness data. Dr. Meyer[3] has found that some types of translucent screens apparently have s-factors which are dependent upon wavelength. Therefore, these equations may prove helpful in specifying tolerances for screens suitable for work with color photography. In any case, they extend the simplicity of mathematical treatment now applicable to Lambert diffusers to many important types of directional diffusing surfaces, and as such should be of interest and use in the motion-picture and television industries.

---

[3] Private communication from Herbert Meyer of the Motion Picture Research Council.

Photography of Motion

By JOHN H. WADDELL

The use of photography for determining velocities, accelerations and degrees of movement in high-speed phenomena as well as in growing plant and animal life is discussed. Focal length of lens, distance from camera to subject, size of subject, corrective angles and magnifications of results are shown to be vital factors in every variety of time-motion study, and recommendations for achieving optimal results are made.

PRECISE MEANS of measuring moving objects is becoming an increasingly important phase of photography. There is a wide interest in studies of motion. Subjects range from growing plants and bodies to artillery shells in flight, and even to the measurement of the velocity of light itself.

Photographs have been made of the human embryo from its conception, through birth, and eventually ending with the human body in death itself. It has been thus possible to measure rates of human growth over the complete life span, from the maximum of just before birth to the final, negative phase when the body becomes slightly smaller in old age.

Time-lapse pictures of the budding and blossoming of a flower are another interesting application of motion photography. In this case the exposure time will be short, but the frequency may be as low as once an hour to get a desired motion picture that can be used for visual observation and analysis.

A popular subject today for such studies is the rate of growth of the fireball of the atom bomb. A typical series of pictures made for this purpose is shown in "The Effects of Atomic Weapons" (Atomic Energy Commission, Washington, D.C., 1950). A picture frequency of about 8,000/sec was used in this instance.

In order that precise measurements of motion may be made, certain primary requirements, and the terms describing them, must be understood, as well as a technique of reading the resulting films.

In the determination of velocities, accelerations and the degree of movement from exposed film, the following must be known: (1) the focal length of the lens; (2) the distance from the camera to the subject; (3) the size of the subject; (4) corrective angles; and (5) the magnification of the reading or transcription system.

Presented on October 16, 1951, at the Society's Convention at Hollywood, by John H. Waddell, Industrial and Technical Photographic Div., Wollensak Optical Co., 850 Hudson Ave., Rochester 21, N.Y. (This paper was first received Nov. 24, 1952, and released July 21, 1953.)

Before entering any discussion of the photography of motion, an understanding of the meaning of velocity is imperative. Most observers think in terms of linear velocity only, in relationship to motion studies, but angular velocity is far more important photographically. One of the first questions to be asked is, "What is the angle of view or coverage of the lens?" This, indirectly, allows the photographer to calculate how far the subject will move during exposure and/or between exposures.

Linear velocity is equal to distance divided by time. Projectiles in flight are measured in feet or meters per second, motor cars in miles per hour, and boats by knots, while plants and animals may be measured in inches per day, week or month. It is possible to photograph these assorted space-time relationships and to show them in the same space-time relationship. The techniques for photographing the various subjects however, must of necessity differ.

Angular velocity technically is the quotient of angle divided by time. More simply, it is the distance the subject will move during the time of exposure in a given field size.

If a projectile is moving at a linear velocity of 1000 fps and if the field size is 1 ft, the projectile will move 1 ft during an exposure time of 0.001 sec, or $\frac{1}{10}$-ft in 0.0001 sec. In 1 μsec. it will move but 0.001 ft, or 0.012 in. If the field size is increased to 100 ft, the image size with the same focal lens is about $\frac{1}{100}$ what it was in the first case. The subject will travel as far as each exposure time given above, but the apparent image on the film is sharper because of its reduced size.

With a picture-taking rate of 1000/sec, one picture would be secured with a 1-ft field. With the 100-ft field, 100 pictures would be obtained.

In the instruction book issued for the Kodak High-Speed Camera, a formula is given for the determination of desirable camera speed (C.S.) for sharp pictures:

$$\text{C.S.} = \frac{40 \times \text{Speed of subject in ips}}{\text{Total width of subject field in in.}}$$

In order to see how this works practically in ballistics:

Projectile speed, 2000 fps or 24,000 ips;

Total width of field, 10 ft or 120 in.;

$$\text{C.S.} = \frac{40 \times 24{,}000}{120} = 8{,}000 \text{ pictures/sec}$$

In the 0.005 sec, 40 pictures will be obtained. If the pictures are taken at 14,000/sec, about 72 pictures will be obtained, requiring about 5 sec projection time.

If the field were 1-ft, 80,000 pictures/sec would be required, while with the 1000-foot field 800 pictures/sec would be adequate.

The above formula does not give the movement of the subject image on the film during exposure. However, with the 10-ft field and with an 8mm camera taking double-width pictures, the film width is 0.4 in. Therefore, the reduction is:

$$\frac{\text{(Field width) 120 in.}}{\text{(Film width) 0.4 in.}} = 300 \text{ times}$$

Table I gives the distance from the camera to the subject and the available lenses to secure this field width.

Table I

Focal length of lens	Distance, camera to subject
1 in.	301 in. (25.08 ft)
35 mm	421.4 in. (35.12 ft)
2 in.	602 in. (50.16 ft)
2½ in.	752.5 in. (62.71 ft)
3 in.	903 in. (75.24 ft)
4 in.	1204 in. (100.33 ft)
6 in.	1806 in. (150.50 ft)
10 in.	3010 in. (250.8 ft)
15 in.	4515 in. (376.25 ft)

It is to be observed that from each of these camera positions, the field size will be the same. And from the comparative standpoint, the depth of field can be the same.

With this reduction in size, and with a velocity of 2000 fps, 4 pictures will be made per foot of travel of the projectile. Therefore, the subject will travel during exposure:

$$2000 \times \frac{1}{8000} \times \frac{1}{6} = 0.0417 \text{ ft or } 0.5 \text{ in.}$$

Fps × Reciprocal of Picture-Taking Rate × Exposure Cycle Rate = Movement of Subject

Based on the 300 times reduction, the image on the film will move during exposure 1/300 of 0.5 in. or 0.00167 in., which is excellent for frame-by-frame analysis.

To go to the other end of the scale to secure the opening of the flower or the growth of a plant, the same type of calculation is required. If a flower takes 4 days to open completely and a 15-sec end sequence is required:

$$15 \text{ sec} \times 24 \text{ pictures/sec} = 360 \text{ pictures}$$

$$4 \text{ days} = 5760 \text{ min}$$

$$\frac{5760}{360} = 16, \text{ or 1 picture every 16 min}$$

One is able to control the exposure of time-lapse photography far more easily than the exposure in high-speed photography.

A man hitting a golf ball, photographed with a 10-ft field, makes an excellent subject at 1000 pictures/sec, while the impact of the club on the ball in a 4-in. field cannot be satisfactorily photographed at 14,000 pictures/sec.

(1) Focal Length of Lens

The focal length of the lens is nominally the distance from the lens to the film plane when the lens is focused at infinity. There is one school of thought which believes that the effective focal length for measurement purposes should be based on the hyperfocal distance rather than the infinity focus.

The comparative change in effective focal length (infinity focus) is given in Table II.

Table II

Nominal effective focal length, in.	Maximum aperture of lenses calculated (*f*-stop)	Hyperfocal distance at maximum aperture,* ft	Correction to be added to effective focal length, in.
1	2.5	33.3	.00118
35mm	2.0	79.1	.00200
2	2.0	166.7	.00200
$2\frac{1}{2}$	2.7	192.9	.00271
3	2.5	300	.00250
4	3.5	380.95	.00351
6	4.5	666.7	.00451
10	4.5	1851.9	.00450
15	5.6	3348	.00560

* With the lens focused on the hyperfocal distance, all objects from half the hyperfocal distance to infinity are in focus. The calculation for hyperfocal distance is based on:

$$H = \frac{f/2}{f/\text{number } x}$$

The circle of confusion is assumed to be 0.001 in.

The ASA standards on lens focal length allow a ±4% deviation from nominal or marked focal length. All lenses to be used for measurement purposes, therefore, should be marked in the EF to the nearest tenth-millimeter or thousandth of an inch.

It is to be pointed out that the focal length will also be a contributing factor in the angular field coverage. The expression "angular coverage" in this paper refers to either vertical or horizontal only, and not to diagonal. Most engineers follow the line of action in either the vertical or horizontal planes in measurement.

$$\tan \tfrac{1}{2} x = \frac{\tfrac{1}{2} \text{ Frame width}}{\text{Focal length}}$$

It can easily be seen that the 4% variation will have a serious effect on angular coverage — and this becomes more critical with longer focal length.

Table III

	Temperature Fahrenheit			
	−65°	0°	70°	150°
Aluminum	−.00186	−.00097	.0000	+.00111
Brass	−.00134	−.00070	.0000	+.00080
Invar	−.000067	−.000035	.0000	+.000040

(2) Distance From Camera to Subject

The distance from the camera to the subject is one of the most confusing points in measurement and designation of focusing scales. ASA has established a standard marking on the camera, "Film Plane" being designated by a circle with a vertical line passing through it. It must be realized, however, that the term "Film Plane" may not mean much to an average user, and this has been modified on Fastax cameras to read "Measure subject distance from here," with the same bisected circle designation. The allowable deviation is then ±2 line widths from the nominal marking on the lens.

Furthermore, on the focusing scale there should be an over-run beyond the infinity marking. Most camera operators do not feel satisfied unless they can go beyond infinity and then come back to infinity when they are focusing.

No reliance should be placed on focusing scales in extreme limits of temperature, the effects of extreme heat or cold becoming more noticeable with longer focal-length lenses. The aerial image should be the standard of focusing under these conditions.

Table III illustrates the change in lens-tube length per unit length for temperature ranges specified by the military forces and those actually occurring in the United States.

It is obvious that if a 10-in. lens tube is used, the back focus will be pushed .019 in. behind the normal film plane with an aluminum tube at −65 F while it will be pulled 0.011 in. ahead of the film plane at +150 F. The above does not take into consideration what takes place in the lens cells themselves. They should be constructed with invar separators.

Besides the focusing scale on lenses for measurement, there should be a temperature-compensating scale. This is doubly imperative because lenses in high-speed photography are in many cases used "wide open." It is also imperative that the materials used for lenses have a minimum coefficient of expansion — and that they should not have a black external finish.

Many high-speed photographers are using infrared filters to accentuate the sky, particularly in missile work. This changes the back focus. The rule for photographing in the near infrared is to increase the back focus 1/88 the normal focal length. There is no effect on the back focus with visible light.

There is another disturbing factor in measurement that is frequently overlooked. It is that of atmospheric convection currents. Most survey work on the desert is done from midnight until sunrise. The currents or "jitter" have a very disturbing effect on camera focus and on the photographic results obtained. Pictures taken with Askania cameras and standard-speed motion-picture cameras at elevations of less than 20° are unique in many respects, but practically useless for a precision measurement. This effect is minimized by elevation and altitude and by shortening of exposure time. High-speed motion pictures are practically free from this effect. The greater the distance from object to the camera, the more "atmospheric jitter" will be present.

(3) Size of Subject

The size of the subject can be used for computation of velocities and field size. The magnification is

$$M = \frac{D - F}{F}, \text{ where}$$

D = distance of object to film plane

F = focal length

The above formula is approximate. A deviation of the exact formula gives the following relationships:

$$M = \frac{X}{F} = \frac{F'}{X'}$$

Reduction is the inverse ratio from the magnification factors given above.

(4) Corrective Angles

The angle of the motion to the camera is important from a number of points of view.

The amateur cinematographer usually learns the hard way that a child on a swing gives the best stroboscopic effect when the camera is 90° to the direction of the swing. It becomes less at 45° and an even picture is obtained head-on. "Panoraming" makes an audience dizzy. But as the camera is focused on a moving subject and follows it, the subject is sharp. This is a practice followed by press photographers and newsreel cameramen.

There are two major types of angular problems which are typical of field installations: that in which the distance to the center of the field is known; and that in which the distance is known to the point where the subject will enter the field. Trigonometry solves these problems as follows:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

In Fig. 1, the case where the distance to the center of the field is known, this triangle requires the solution of two triangles in the following steps:

A = 30° angle of view
A′ = A″ = 15°
B = 95°
C = 55°
D = 20° angle of flight
b′ = 100 distance of center of field
a′ + a″ = a path of the subject

In triangle I

$$\frac{a'}{\sin A'} = \frac{d}{\sin B}$$

In triangle II

$$\frac{a''}{\sin A''} = \frac{d}{\sin C}$$

Solving

$$\frac{a'}{\sin 15°} = \frac{100}{\sin 95°}$$

$$a' = 26 \text{ ft}$$

and

$$\frac{a''}{\sin 15°} = \frac{100}{\sin 55°}$$

$$a'' = 31.5 \text{ ft}$$

Therefore

$$a' + a'' = 57.5 \text{ ft}$$

And now, the second problem, as shown in Fig. 2:

A = 30° angle of view
A′ = A″ = 15°
B = 95°
C = 55°
D = 20°
d = 100

$$\cos A'' = \frac{d}{c}$$

$$\cos 15° = \frac{100}{c}$$

$$c = \frac{100}{.966} = 103.5 \text{ ft}$$

$$a = \frac{c \sin A}{\sin c}$$

$$= \frac{103.5 \times \sin 30°}{\sin 55°}$$

$$= 63 \text{ ft}$$

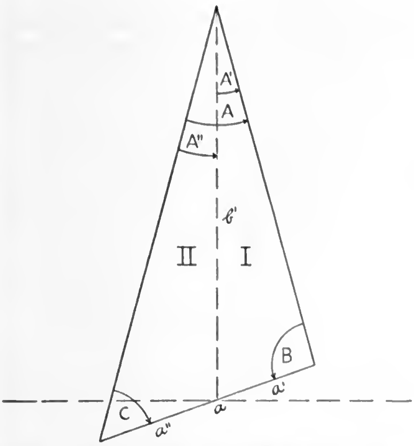


Fig. 1. Flight path where subject bisects known distance from camera.

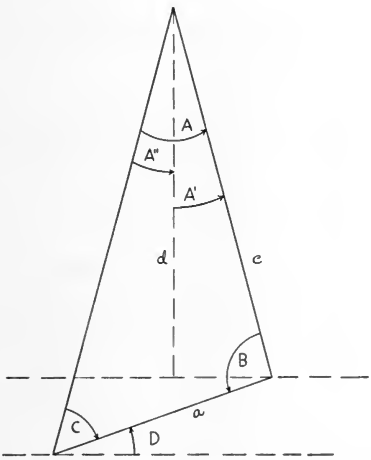


Fig. 2. Flight path when distance is known where subject enters field.

The above assumptions are based on optical systems which produce distortion-free films. In order to check the distortion of the system, a sheet of cross-section paper can be photographed and then the distance between lines checked with a microscope over the whole field. The objectives for measurement selected must be good ones however.

(5) The Reading System

In the reading of the film, the projection optics should be equal in resolution and field flatness to the exposing optics. In order to cut costs of manufacture, inferior optics are often used, as is sometimes apparent in slide and motion-picture projectors. The projection lens on the time-and-motion study projector should be a photographic objective, because many users project their films frame by frame, particularly those taken with high-speed motion-picture cameras. The focal length of the lenses should be accurately marked, so that the user can make good measurements.

In many microfilm readers, the same condition exists. It is becoming imperative that the magnification factors be calibrated for the study of motion. The finest of cameras will be wasted if the resultant film is studied through poor reproduction optics.

One manufacturer provides a test film taken with the camera when ready for delivery. The film consists of a National Bureau of Standards Resolution Test Chart as photographed with that particular camera. The test chart shows resolving power up to 56 lines/mm. It has been demonstrated many times that the best resolution that can be shown on some types of optical comparators and ground-glass screen projectors is a resolving power of one-half or less than that obtained through a straight optical system. A resolution of 56 lines/mm is approaching the limit of many high-speed panchromatic emulsions.

Milk-bottle glass lenses are a cheap, time-wasting and worthless means of examining fine, accurately made films.

Exposure time should be critically examined. Theoretically, exposure should be based on a square-top wave. The exposing device should open *instantaneously*, remain open for the desired time and then close *instantaneously*. No devices yet available follow this pattern.

High-speed gas-discharge tubes have a decay time, focal-plane shutters move across the film, barrel shutters and rotating prisms follow a sine wave, mechanical shutters have both opening and closing time. The fastest-operating shutters are the piezo-electric or electro-optical shutters, which operate off a single pulse such as a radar pulse.

An interesting question was raised by one high-speed photographic user. He was using a spark for schlieren photography. The photographs showed that the schlieren picture exposure was 1 μsec. A calibration was desired, and a streak picture of the spark discharge was therefore made. It was found that the discharge required 100 μsec to take place, but that the actinic photographic exposure took place in only 1 μsec.

In the Fastax camera, the approximate exposure time is given at $\frac{1}{6}$ times the reciprocal of the picture-taking rate. At 1000 pictures/sec, the exposure time is 0.17 msec; at 15,000 pictures/sec, 12 μsec. With the Edgerton flash unit designed for the Kodak and Fastax cameras, the exposure time is $1\frac{1}{2}$ μsec. With the rotating prism, the image sweeps with the film and a highly resolved image is obtained. If the flash unit is used without the prism, the image is smeared by the following amounts:

Film velocity, fps	*Image movement during exposure, in.*
1½-μsec flash	
5	0.00009
50	0.0009
100	0.0018
200	0.0036
1000	0.018
20-μsec flash	
5	0.0012
50	0.012
100	0.024
200	0.048
1000	0.240

Therefore, if a limit of 0.00025 in. is placed as the upper tolerable limit of image smear, the data are given below to show the time of exposure and maximum velocity to produce this limit.

Exposure, sec	*Film velocity, ips*
0.000001	250.0
0.00001	25.0
0.0001	2.5
0.001	0.25
0.01	0.025
0.1	0.0025
1.0	0.00025

It can easily be seen that for film velocities of more than 20 fps, image compensation is useful.

With focal-plane shutter, 1/1,000 in. is the lower useful limit at present; with the compound shutter 1/800 in. is the lower limit while other shutters fall in this grouping. The electric spark has a low limit of about $\frac{1}{10}$ μsec, while the piezo-electric effect can be operated at 1/1,000 μsec.

Back in 1880 Muybridge used multiple cameras to get the trotting horse pictures. Multiple cameras are used today to secure time resolution to a high degree, but they cover the same field of view.

In such an arrangement, all the cameras must be receiving the same time signal to drive the gas-discharge (neon) timing light or the spark. Each light must begin to function some time after the cameras have started, so that zero time is established on all films. With rotating-prism cameras driven by series motors, the prisms are all in random positions. It is possible to secure measurements to an accuracy of 1 μsec by using 14 cameras at 16,000 pictures/sec and assuming the exposure time of 10 μsec per picture.

By reading the leading edge of the motion, and with milli-second timing marks establishing the angle of prism rotation with respect to the next camera, the readings from 14 films will give the microsecond accuracy.

A formula for the establishment of

number of cameras with random shutter positions, constant exposure times, and other factors, is given in a paper by Wilkinson and Romig.*

The use of 10 or 20 less expensive cameras with high resolution will often produce space-time resolution over a *much longer* period of time than will a single ultra-high-speed camera with fair resolution or with limited picture-taking capacity.

Another extremely valuable aid in the photography of motion is the use of stereoscopy. The perception of depth achieved through the two eyes of human vision assists materially in the analysis of space motion. In some cases, people born with one eye learn to visualize this differentiation of space, but it is, of course, far more readily observed with the use of two eyes. Stereoscopy, with an interpupillary distance of approximately $2\frac{1}{2}$ inches can be practiced up to distances of 1000 to 2500 ft. Greater distance perception can be obtained by artificially increasing the interpupillary distance to a base of from 6 in. to 20 ft or more. Where the broad base is used, however, there should be nothing in the foreground.

A number of devices have been used in stereoscopic photography. The most common are twin-lens cameras with the $2\frac{1}{2}$-in. interpupillary distance; single-lens cameras with mirror or prism beam splitters (this includes the use of wedge prisms); beam splitters with individual lenses; single cameras and single lenses moved through a known interpupillary distance (this latter method is used in aerial photography). There are advantages and disadvantages to each of the above methods. In order to broaden the base of high-speed motion picture photography, there have been stereoscopic devices designed to assist in the analysis of motion.

As a further aid in the study of motion, reticles and fiducial marks are used to help establish the base lines for measurement. In the case of intermittent and still photography, the aperture plate may be notched, or crosshairs may be placed in the plane of the image. In the case of high-speed motion-picture cameras, there has been designed a system which consists of moving the objective lens ahead of the point at which it would normally be used. The image from the objective lens is laid down on a collecting lens which has a reticle engraved upon it. A one-to-one relay lens system then lays the image down at the film plane. Because the image is in a reverse position, compared with the normal photographic procedure, projecting the films is accomplished by putting a roof prism in front of the projection lens to get the picture back into normal orientation.

The measurement of the film for motion remains to be discussed. Projectors are normally used for measuring purposes in the case of motion-picture film. The projector will, of course, have a certain amount of natural jump, and therefore measurement by this means should be confined to qualitative factors only.

Frame-by-frame analysis of the individual pictures is far more important. This is aided by fiducial marks, often on the original film. Today most projectors of this type back-project the film onto a ground-glass screen. Where the subject is small, however, the grain structure of the screen may interfere seriously with the ability to measure the film. As was mentioned above, the object may actually move during exposure, and, therefore, it becomes quite difficult to establish a point of measurement. The ordinary procedure in such a case is to measure the leading edge of the smear. Where wide-angle lenses are used, or where there is no change in

* Roger Wilkinson and Harry Romig, "Space-time relationships with multiple-camera installations," presented on October 8, 1952, at the Society's Convention at Washington, D.C. Early publication in the *Journal* is planned.

the magnification of the projection system, templates can be designed and used to cover the necessary distance or angular calibrations.

The ideal system would be to take films which have fiducial marks (used with intermittent cameras) or projected reticles (used with continuous cameras) and project the image at 10 × magnification onto a clear-glass screen. Use a mark (engraved) on the clear screen for focusing the eyepiece, and fiducial or reticle marks for the superimposition of the projected film image. A 5 × eyepiece on a pantograph arrangement may then be used to measure the position of the test object on the film. The pantograph is so arranged that the $\pm x$ and y values from the center may be noted on a counter. Alternatively, a prepared linear scale may be engraved on a clear-glass screen at any desired footage or angular base.

If the camera is reducing the original subject 100× and the projector is working at 50× magnification, it is apparent that the subject is one-half normal size, an easily measured image. Even if there is motion in the subject, the "fuzzy" leading edge will still be a good point to measure from picture to picture. The picture or subject does not have to be frozen for accurate readings.

Another instrument valuable for measurement of motion is the densitometer. This instrument is used for brightness or intensity measurements. It is possible to make very good measurements with the frame-by-frame or streak cameras by correlating time and density measurements from any part of the film. Flames, explosions, and detonations are typical subjects for these studies.

This technique is not valid for reversal film, but only for negative. In a reversal film, with a controlled second exposure, the processing will alter the desired result.

H&D strips are placed on the negative or on a strip of negative material of the same emulsion number as the test film. A test negative is made of a subject of known brightness such as the sun. It may be necessary to reduce the intensity with neutral-density filters in order to place it on the midpoint (such as a density of 1.2) of the straight-line portion of the H&D curve. A plot is then made of time of exposure (preferably to the millisecond) and obtained density. That is the starting point even with density-correcting filters. For more intense incandescent points, heavier filters are used; for subjects of moderate brightness, more transparent filters, or none at all, may be employed. Three color-separation negatives may be made this way, and individual color prints made from any point on the film, providing zero time marks start after the film has started, and the same oscillator is used for timing purposes. By using sharper-cut color filters, measurements can be made in any portion of the spectrum from the near-ultraviolet to the infrared for the broad-band spectral analysis of flame components.

The reading of films for measurement of motion is oftentimes quite laborious, but it pays dividends from the standpoint of accuracy.

In conclusion, then, it may be said that the photography of motion is a fairly simple proposition if one takes into consideration the space-time relationship, the rate of growth, angular velocities, and endeavors at every step to ensure accurate measurements.

The BRL-NGF Cinetheodolite

By SIDNEY M. LIPTON and KENNARD R. SAFFER

A number of incomplete Askania cinetheodolites are being extensively rehabilitated and modified under a joint program of the Navy Bureau of Ordnance and the Army Ordnance Ballistic Research Laboratories. New features include improved bearings, data circles, complete replacement of all mount components except carriage castings, a Mitchell high-speed camera movement operating synchronously at 16, 32 or 64 frames/sec, 500-ft magazines, and telescopic optical systems of 60-, 96-, 144- and 180-in. focal lengths.

THROUGH a joint program of the Ballistic Research Laboratories of the Army Ordnance Department, and the Naval Gun Factory under the direction of the Navy Bureau of Ordnance, the modification of a group of existing incomplete Askania cinetheodolites has resulted in a new, improved and radically modified cinetheodolite. At the present time these new instruments are in the process of construction and the first prototype model is nearing completion.

Many of the features planned for this instrument have previously been tried out in other instruments but several proposed features have yet to be actually field tested.

The improved accuracies of bearings and circles have already been demonstrated in similar cinetheodolites furnished to the U.S. Naval Ordnance Test Station, Inyokern, Calif. Long focal-length telescopic systems, and high variable-speed cameras with large film capacity have been used at White Sands Proving Ground, Las Cruces, N.M., in similar cinetheodolites. The use of a synchronously operated multispeed camera, a range of quickly changeable long focal lengths, and the use of the particular type of target-acquisition system employed here have not yet been field tested. The configuration of the camera drum, the incorporation of a standard high-speed Mitchell movement, the provision for phasing in the shutter operation with a central signal, the arrangement of the 500-ft magazines, the provision for a quick field check of infinity focus and collimation and the use of standard-frequency power for the motor drive are new as far as the WSPG range cinetheodolite instrumentation is concerned.

This instrument is planned for use at the White Sands Range for both Army and Navy projects and the design fea-

---

Presented on May 1, 1953, at the Society's Convention at Los Angeles by Sidney M. Lipton (who read the paper), Bendix Radio Communications Div., Bendix Aviation Corp., Baltimore, Md. (formerly of Ballistic Research Laboratories, Aberdeen Proving Ground, Md.), and Kennard R. Saffer, U.S. Naval Gun Factory, Washington, D.C.
(This paper was received on May 4, 1953.)

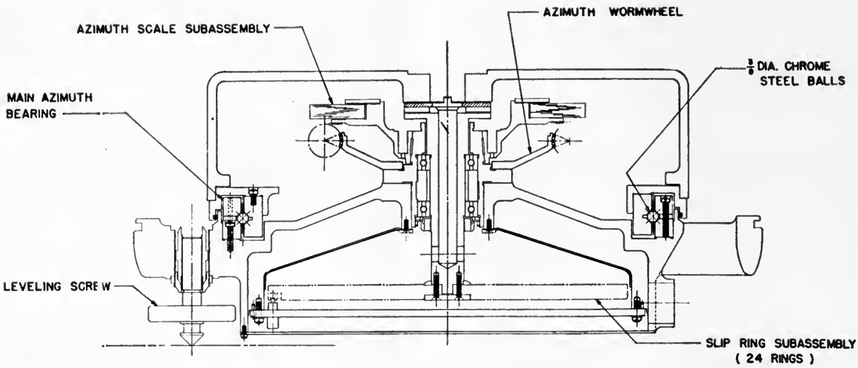


Fig. 1. Mounting-base assembly.

tures of this cinetheodolite have reflected the particular requirements of this range.

It was found that the existing German design of the main azimuth bearing and the elevation trunnion bearings were not suitable for photographing fast moving objects. Specifications were set forth by ordnance test stations requiring a theodolite to train in azimuth about its vertical axis within a tolerance of plus or minus five seconds of arc. Likewise the same tolerance was specified for the rotation of the camera drum about the horizontal axis. The glass scales used for recording angles of azimuth and elevation were required to be engraved to an accuracy of two seconds of arc.

It was also evident that the picture rate of the German Askania camera of 4 frames/sec was insufficient. Likewise, the German 30.0- and 60.0-cm focal-length photographic-objective lenses were not capable of photographing targets at long range.

Previously designed azimuth bearings for this instrument, which were successfully used at the U.S. Naval Ordnance Test Station, were found to meet these required tolerances. The cross-sectional area of the bearing for this instrument was increased for ease of manufacture.

Figure 1 shows a cross-section view of the main azimuth bearing and the center spindle assembly.

(a) The azimuth bearing consists of an inner and outer race. The outer race is divided into two parts separated by a spacer which is ground to the proper thickness to eliminate any shake between the balls and the race.

(b) The center-spindle assembly is fitted to the base. The vertical axis of the instrument is established by the rotation of the spindle on precision ball bearings. These bearings have an ABEC-7 rating. From this axis the outside diameter of the main azimuth bearing seat is machined concentric within 0.0002 in.

(c) After the bearing is assembled and the top and bottom surfaces of the complete bearing are checked for parallelism, it is then placed in the base. The bearing seat on the base is scraped so that the outer race can be properly seated and secured without introducing any rotational error. The inner race is seated to the rotatable carriage in a like manner and then secured. The rotational force is transmitted from the base to the carriage through 68 $\frac{3}{8}$-in. diameter chrome steel balls.

(d) The azimuth scale mount is then fitted to the center-spindle housing on a tapered surface. With the glass scale loosely placed in its mount, the assembly is rotated about the tapered fit. By means of eight concentric marks on the glass scale, a concentricity check is made on each mark viewed through a 100-power microscope. After the scale is adjusted truly concentric with the vertical axis of the instrument, the scale retainer is secured and the glass scale cemented in place. By this method of assembly the concentricity error between the glass scale and the main azimuth bearing is held to an absolute minimum. The rotatable carriage is mounted to the inner race of the main azimuth bearing by a close pilot fit which is machined concentric to the rotation of the azimuth bearing. A coupling arrangement is provided for the mounting of the carriage to the center spindle to offset possible binding between the carriage, which finds its center about the main azimuth bearing, and the vertical axis of the base.

(e) Twenty-four slip rings are provided to allow for continuous rotation in azimuth. The brush-holder mount is designed so that the replacement of brushes would be relatively simple. Metal brushes are used to keep the voltage drop to a minimum. Electrical connectors are provided on the underside of the base to supply power for the operation of the camera and other electrical units.

(f) The carriage assembly trains in azimuth about the vertical axis by means of a worm-and-gear drive operated by a handwheel. The handwheel subassembly provides a two-speed gear ratio, namely, 1° rotation of the instrument per one turn of the handwheel in slow speed and 4° per turn in high speed. To change from one ratio to another, the handwheel is either pulled or pushed in an axial direction.

(g) The azimuth and elevation internal glass scales are made of plate glass to Bureau of Ordnance specifications. They are engraved every one-half degree to within an accuracy of two seconds of arc.

The azimuth scale mount can be rotated by means of a spring-loaded clutch enabling the operator to align the zero point on the scale to any desired position.

Figure 2 is a cross-section view of the assembled carriage and slip-ring assembly.

(a) Microscopes of 30-power are provided on the azimuth and elevation sides of the instrument. When the positioning lever is depressed, the microscope is inserted into the optical path of the scale-projection system. This enables the operator to read the internal scales directly in degrees and minutes. A spring tension on the positioning lever requires the operator to hold the microscope in a reading position. As soon as pressure is released from the lever the microscope is retracted from the optical path of the scale-projection system. This feature assures an uninterrupted projection of the scale readings to the film plane when the camera is in operation. The azimuth and elevation angles are simultaneously photographed with the target. The internal scales are illuminated by flashlamp units which are synchronized with the camera shutter so as to allow proper illumination for projecting the scale readings to the film plane. The advantage of photographically recording the azimuth and elevation angles with the target is that recording errors due to rate of change in tracking error are eliminated. This method provides accurate data for determining and recording the trajectory of the target.

(b) The camera drum rotates in precision ball bearings about the horizontal axis by means of a worm-and-gear drive operated by a handwheel. The handwheel subassembly is provided with the same gear ratios as those in the azimuth drive. The ball bearings used for the rotation of the camera drum about the horizontal axis have an ABEC-9 rating.

(c) The camera-drum trunnions are machined concentric to the horizontal axis. After the drum is assembled in the trunnion bearings on the carriage, the horizontal axis is checked for parallelism to the rotation of the main azimuth bearing. The elevation glass scale is then mounted on its housing. By means

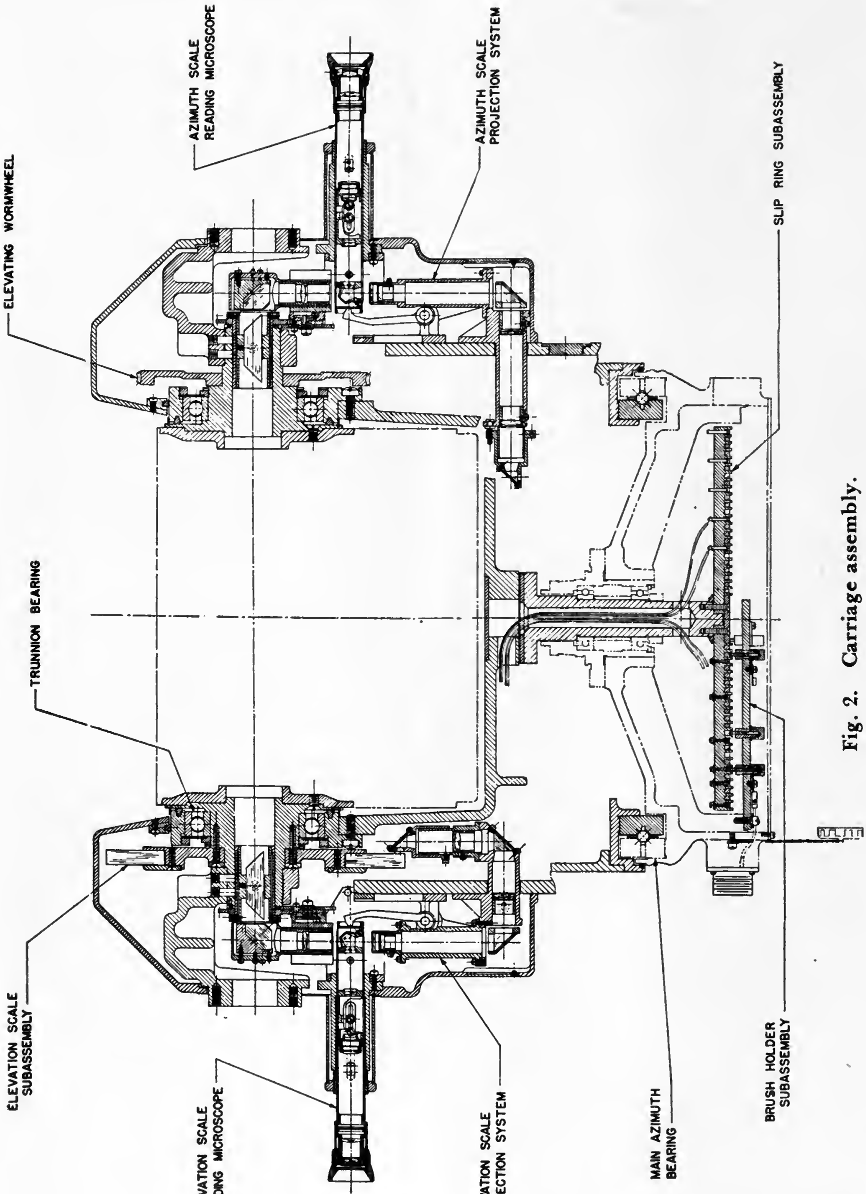


Fig. 2. Carriage assembly.

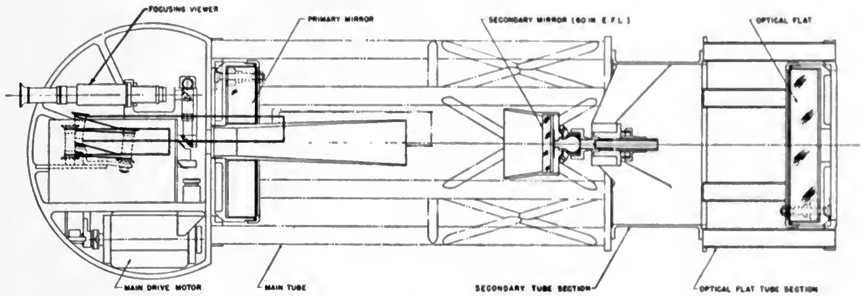


Fig. 3. Side elevation of camera and main optical system (60-in. E.F.L.) with focusing attachment.

of eight concentric marks on the glass scale, it is centered about the horizontal axis. The scale retainer is then secured and the scale is cemented in place.

(d) The guiding telescope is a monocular right-angle type with interchangeable eyepieces to provide for magnification of 12- and 20-power. The eyepieces can be focused from −2 to +4 diopters. The two eyepieces can be interchanged by pulling one of the complete assemblies from the body of the telescope. By means of a piloting fit and a positioning dowel, the other eyepiece assembly can be inserted into the telescope body. It is held in place by three spring-loaded detents and is secured by a lock screw.

Crossline illumination is provided for the reticle. The light intensity can be varied by a rheostat for sighting under adverse light conditions.

The complete telescope weighs 7 lb and has a moment of 42 in-lb about the horizontal axis. The telescope mounting bracket is counterbalanced to offset this moment.

The optical characteristics of the telescope are as follows:

	Low Power	*High Power*
Magnification	12×	20×
True field	5°	2° 45′
Eye distance	24.5 mm	15.0 mm
Exit pupil	5.0	3.0 mm

When the field location of these instruments is a considerable distance from the starting point, the target will not be visible initially to the tracker due to differences in elevation, atmospheric conditions or reduction in size of image caused by long horizontal lines of sight.

To enable the tracker to follow the target even though not visible, a remote-indication system will be set up in the field to transmit to these instruments electrical signals which will be a function of the relative position of the target.

The reception of such signals at the instrument will result in a galvanometer-pointer deflection, visible to the tracker. By tracking the instrument properly, each tracker will tend to keep this pointer deflection at the zero mark. This will mean that the target is in his field of view. By occasionally checking in the guiding telescope, the tracker will eventually sight the target and continue tracking thereafter visually.

The main optical system, shown in Figs. 3, 4 and 5, consists of a Cassegrainian telescope. There are four focal lengths available: 60, 96, 144 and 180 in. Figure 3 shows the layout for the 60-in. system. The clear aperture of the main mirror is $7\frac{15}{16}$ in. and its focal length is 24 in. The main mirror is held in an adjustable cell mount in which tilting of the mirror is possible so that it may be aligned correctly with reference to the

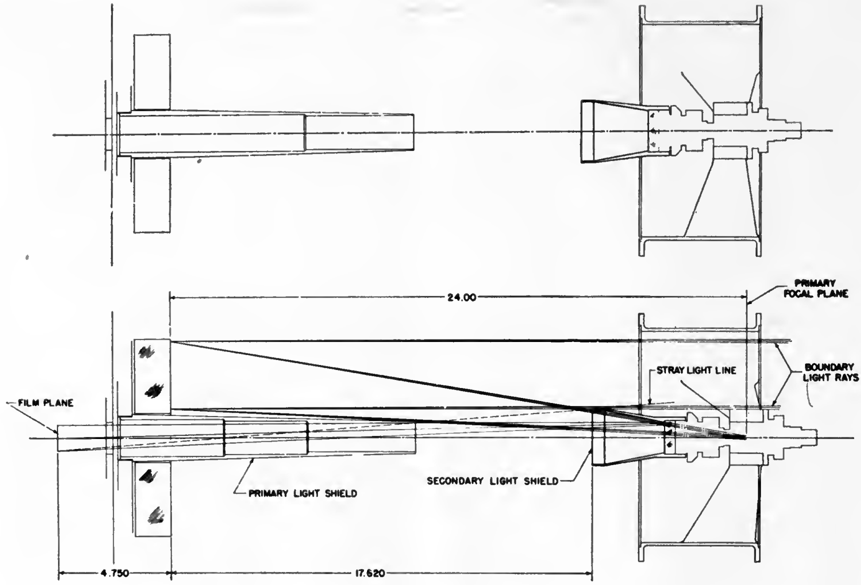


Fig. 4. Optical diagram for (above) 144-in. and (below) 180-in. E.F.L. system.

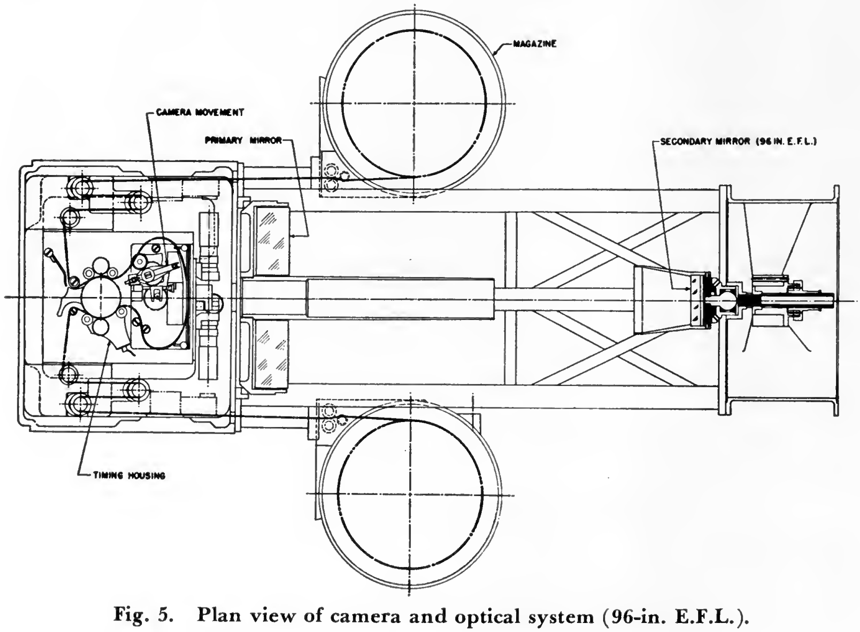


Fig. 5. Plan view of camera and optical system (96-in. E.F.L.).

film plane and the secondary mirror. The secondary mirrors are mounted in cells which are assembled in holders in which tilting and translation along the optical axis can be effected in small increments by means of setscrews, a ball-and-socket joint, bearing surfaces and fine threads. Movements along the axis may be controlled and repeated to 0.001 in. by means of a vernier screw. The final position of the mirror is then established by a locking nut. The secondary mirror assembly is fitted into a small central cylinder, web-supported, which is an integral part of an aluminum-alloy housing. This housing is a separate section of the main telescope tube which may quickly be removed and exchanged for another similar housing containing a different secondary mirror providing a different equivalent focal length for the main optical system. Once each secondary mirror has been adjusted and collimated with the main mirror, removing it with its housing and later replacing it, when necessary, should not change its previous position since locating rings and a key will re-position it to a few thousandths of an inch of its previous location; the locating rings are hard steel inserts which prevent translation, the key prevents rotation, and a mating steel butting surface maintains the correct distance from the main mirror.

This secondary aluminum-alloy housing is a casting designed to fit a particular secondary-mirror assembly; each instrument will have four different secondary-mirror and housing assemblies.

In the field, the instrument operator may determine the correct infinity focal-point setting of the secondary mirror by means of an autocollimating type arrangement which he can quickly assemble and disassemble. Figure 3 illustrates this apparatus, which consists of an optical flat, a mirror, reticle and prism arrangement, a 2-w zirconium-arc source and a viewing microscope with a 40-mm objective.

An 8-in. optical flat in an adjustable cell-holder assembly is mounted on the end of the secondary housing. A bracket containing the microscope, mirror, reticle and prisms is inserted in the camera drum and locked into position. The zirconium-arc lamp is connected into position, so that its light is directed through the prisms and illuminates the reticle. The light goes through the main mirror system to the optical flat and then back again through the main mirror system where an image of the reticle is formed near the illuminated reticle pattern. After focusing the microscope on the illuminated reticle, the operator then translates the secondary along the optical axis until the image of the illuminated reticle is also in focus. For an object distance other than infinity, the secondary mirror is then moved an additional precalculated distance away from the main mirror. In this manner, the optical system may be checked each time before use, if, for example, temperature differences are such as to cause expansion or contraction of the structure between mirrors.

The main tube has an open lattice-work construction consisting of end flanges of aluminum alloy and connecting thin-wall steel tubing (0.032-in. wall). The deflection of this main tube, assembled with a secondary mirror housing in operating condition, has been measured and found to be 0.001 in. from vertical to horizontal position. This is a systematic error which may be corrected for in the final reduction of the film data.

Openings have been provided in the main tube, near the main mirror end, to allow for removing the mirror cell and also for inserting the main mirror cover.

The entire main optical-system assembly, without the magazines attached, weighs 32 lb and exerts a moment about the trunnion centerline of 240 in-lb. With magazines loaded (total of 500 ft of film), these quantities become 40 lb and 360 in-lb.

Counterbalancing of this system is effected by the camera-drum housing

Table I. Main Optical System Characteristics.

Effective focal length, in.	60	96	144	180
Amplification	2.5	4.0	6.0	7.5
Distance between primary and secondary, in.	15.786	18.250	19.893	20.618
Area obstructing primary aperture, sq in.	13.30	9.18	6.66	5.47
Net primary area, sq in.	36.18	40.31	42.83	44.01
Secondary clear aperture, in.	3.00	2.10	1.51	1.24
Ratio of central obstruction diameter to primary diameter, %	51.9	43.1	36.7	33.3
Ratio of central obstruction area to primary area, %	26.9	18.5	13.5	11.1
Net focal ratio	8.84	13.41	19.51	24.06

Clear aperture of primary	7.9375	in.
Area of primary	49.5	sq in.
Focal length of primary	24.0	in.
Distance of film plane behind primary	4.75	in.
Diameter of image field at film plane	1.062	in.

design and by external counterweights. The semicylindrical shape of the camera drum and its point of suspension on the trunnion axis place most of its weight behind the trunnions. The camera-drum covers are of steel while the drum itself is aluminum alloy; these covers also help in counterbalancing.

Figure 4, showing the arrangement of the 144-in. and 180-in. focal-length systems, shows also a typical ray tracing. A light shield is used both at the main mirror and at the secondary mirror to prevent stray light from entering the system. These shields are designed to use as much light-collecting area of the main mirror as possible.

Table I, giving the main optical-system characteristics, shows the amount of light which is obstructed because of the secondary mirror cell, its supporting structure and the light shields for the different secondary mirrors. The effective focal ratios are 8.84, 13.41, 19.51 and 24.06.

Figure 5, with the 96-in. focal-length system, shows the film path and the camera layout. The size of the image field at the film frame is 0.7 in. square. The camera drum contains the camera mechanism, the motor and gear drive, a timing-lamp housing, a frame counter, a gaseous discharge tube (Edgerton lamp) and a lamp trigger pickup and amplifier.

The magazines are placed outside the drum, one on either side of the main tube, so that it is possible to plunge the instrument, or turn the main tube and drum through an elevation angle of 180°. Each magazine can hold 500 ft of 35mm film. Laboratory tests have indicated no appreciable increase in torque when the film roll is in a horizontal position in the magazine, when the film edge slides on the inner surface directly or rests on a thin aluminum disc which revolves with the film roll. The take-up magazine is equipped with a 1/40-hp universal motor which operates between approximately 600 and 1000 rpm; the connection between the motor shaft and magazine shaft is through a 1:3.5 pulley ratio using a Gilmer timing belt. This motor, when stalled under these conditions, does not heat up excessively.

The camera mechanism is a standard Mitchell high-speed 35mm movement. This has been left assembled in its housing which has been stripped down, eliminating such features as are not required in this application, such as rack-over inserts and doors. Additional com-

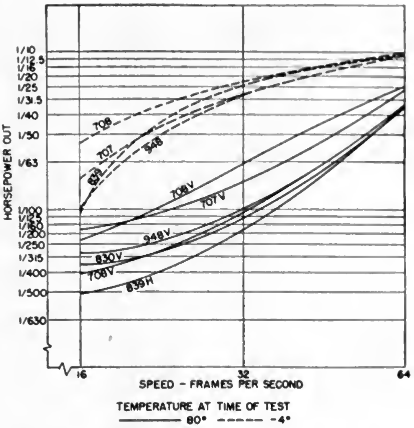


Fig. 6. Horsepower requirements for 35mm Mitchell high-speed movement at ambient and low temperatures.

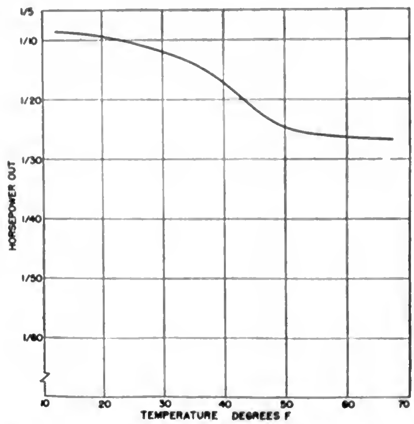


Fig. 7. Horsepower requirements for 35mm Mitchell high-speed movement operating at 32 frames/sec.

ponents have been eliminated or modified; the differential unit for shutter movement has been omitted; the shutter opening will be varied in 15° increments, while the movement is stationary, by means of a knob and a series of locating slots. The shutter shaft has been shortened. Some of the input gears have been eliminated and new gears with a particular ratio added. The camera box is positioned on its side, relative to its normal position. The film entry opening has been cut out to the edge of the camera box and a similar opening has been placed on the opposite side. The film enters and leaves in an edge up position. The holddown-roller assembly which holds the incoming film against the main drive sprocket has been modified to include a double pip-time lamp housing. The buckle switch has been shifted in location relative to the take-up side of the main film-drive sprocket. Additional guide rollers have been placed in the feed and take-up sides about the film-drive unit for proper guidance of the film.

The main drive motor is located in the lower compartment of the camera drum and is supported in a bracket in which

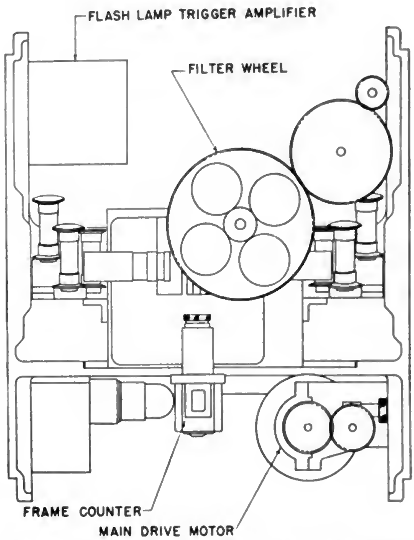


Fig. 8. Front elevation of camera drum.

the outer motor-housing ends are held in bearings; by means of a gear connected on one end of this housing and a mating gear and knob, the latter located outside the drum, the motor frame may be rotated and locked. The motor is $3\frac{1}{4}$ in. in diameter by $4\frac{1}{2}$ in. long. Its out-

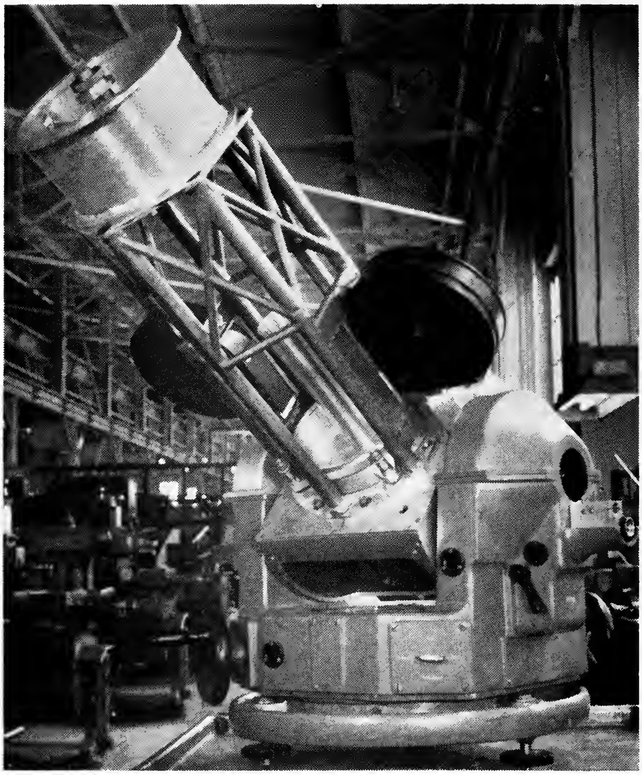


Fig. 9. Prototype of main tube assembly and camera drum.

put shaft is connected to a small gearbox which is in turn connected to the input of the camera gear mechanism.

The design has been arranged so that either of two types of motors may be used. The first or preferred type is a motor now in the process of development. It is a multifrequency synchronous motor of approximately 1/8-hp rating, designed to operate at any one of three frequencies: 60, 120 or 240 cycles/sec at approximately 115, 230 or 460 v, giving speeds of 1800, 3600 and 7200 rpm, respectively. This operation will provide film rates of 16, 32 or 64 frames/sec. This selection of frame rates is available to the operator by means of a switch.

The second type of motor is a conventional single-frequency (60 cycles/sec) single-speed, 110-v a-c synchronous, hysteresis type, 1800-rpm 1/20-hp rating. It can be operated through gearboxes, which must be changed before operation, to provide film rates of 16, 32 or 64 frames/sec.

The set of curves in Fig. 6 shows the various horsepower requirements at different frame speeds at normal temperatures. Laboratory tests were made with Mitchell high-speed movements at the three different frame rates both at normal and cold temperatures to determine the required torque output from a synchronous motor. Both old and new film movements were used. Figure 7 shows a typical curve of temperature affecting camera power requirements.

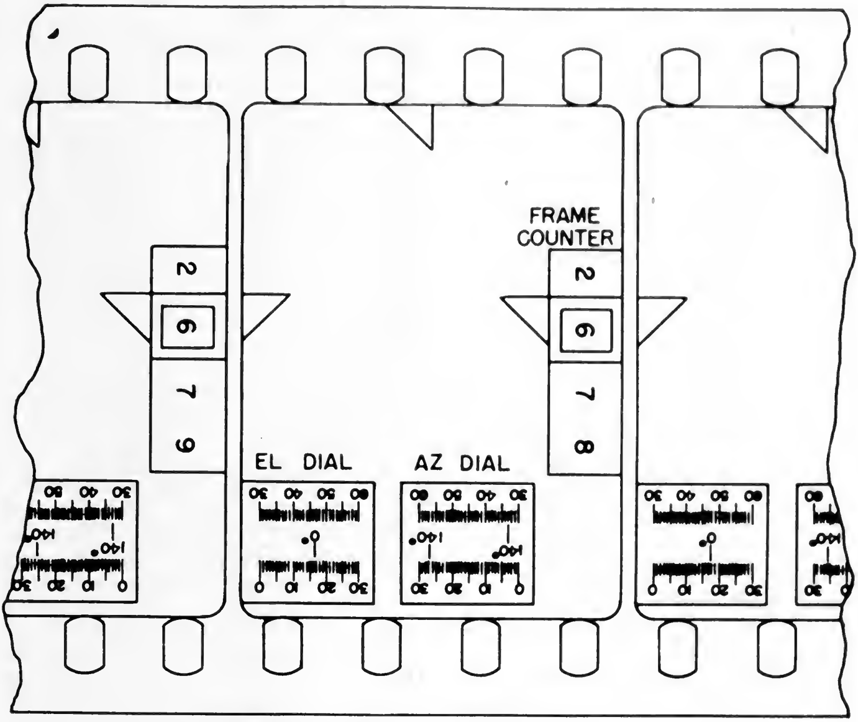


Fig. 10. 35mm frame presentation.

It is noted that from approximately 50 F upwards, the torque requirements are essentially the same, whereas around 0 F the torque requirements are approximately doubled. These results show at normal temperatures, approximately 1/200 hp for 16 frames/sec, 1/100 hp for 32 frames/sec, and 1/20 hp for 64 frames/sec. A value of 1/15 hp was assumed to be a normally desirable capacity; the actual motor may prove to be closer to 1/8 hp.

The motor may be brought to its highest operating speed gradually by either the use of a variable-frequency input to the motor amplifier or by going through the lower discreet frame rates first. When synchronous speed is reached, the frequency input to the motor amplifier comes from a frequency standard.

Figure 8 is a front-elevation view of the camera drum. A counter is located in the motor compartment and is geared to the camera mechanism to show successive frame counts. A gaseous discharge tube illuminates this counter which serves as an object for a lens-and-prism arrangement which produces an image on the film. One leaf of the adjustable shutter has a small slug of permeable iron mounted on it. An electromagnet is mounted on the camera body so that the outside edge of its core is close to the rotating shutter slug, producing a pulse which, when fed into a trigger amplifier, flashes the Edgerton lamps in the instrument; one lamp is located at the azimuth dial, one at the elevation dial and the other at the frame counter. The pickup coil is located so that the rotating slug will produce a signal when the center of the shutter opening is at the center of the film-frame opening. When the shutter opening is changed, a variable resistance is set to produce enough pulse delay so that it still represents the center of the shutter opening at the center of the film frame. The instrument circuit is also designed to cause the Edgerton lamps to be flashed from external central timing pulses. The pulses from the shutter pickup are compared to the central timing pulses selected by the operator at 16, 32 or 64 frames/sec on a small dual tube oscilloscope located on the pedestal of the instrument; the motor frame is then moved until the pulses coincide in phase. The film is receiving central timing pulses as light pips which appear as 100 pulses/sec and coded elapsed time every second. Therefore, film records from all similar instrumentation on the same range may be easily compared together for the same time interval. A filter wheel containing four Wratten Series VI filters is located close by and in front of the film-frame aperture.

Figure 9 shows the prototype main optical tube and camera drum when the first unit was being constructed.

Figure 10 shows the film frame presentation, with azimuth, elevation and frame-counter dials and fiducial marks.

Discussion

Walter Beyer (*Paramount Studios*): In connection with the Mitchell movement I would like to know whether you replaced the shutter with another type?

Mr. Lipton: We are not using the venetian blind shutter. We are using the rotating, variable open type exactly as used on the Mitchell movement.

Mr. Beyer: I also want to mention that I spent 15 years in Germany with the company that manufactured these cinetheodolites, and I want to congratulate you on the improvements you have made.

Mr. Lipton: Thank you.

Mrs. Amy E. Griffin (*Naval Ordnance Test Station*): Have you given much thought to the problem of synchronizing the camera?

Mr. Lipton: I believe I mentioned that we are going to use synchronization in this system. The central time station will generate pulses at the frame rate at which the camera will be used. For example, they will generate 64 pulses per second to each field station. These will feed into a divider from which the operator will select 16, 32 or 64 pulses per second, corresponding to the frame rate at which he will operate the camera.

Mrs. Griffin: Do you have enough experience with these lenses to know how long they will stay in focus because of temperature conditions?

Mr. Lipton: We've had quite a bit of experience. What we normally do is check each day before shooting to make sure they are in focus. If we have a particular object distance and are intending to use the instrument for that, we have a calibration chart to show how much to move the secondary mirror for that particular object. For a short period of time, for example an hour, the focus will not change and, by the method we have outlined, it should be relatively simple for the operator to determine first the infinity focus position, because of the current temperature and light conditions, and then by the use of the precalculated chart, for example, move the secondary mirror the required amount for the object distance. I think this type of system has been used in the field, not precisely in the way I have described it, but by the same general philosophy of adjustment.

Mrs. Griffin: The reason I am interested is because we have used Cassegrainian lenses and then practically stopped using them because we couldn't keep them in focus long enough. I think the secondary mirror needs to have a very stable mount and one which will not vibrate and shake with the instrument as it is being used. We have pretty good luck with all refraction-type lenses.

16mm Projector for Full-Storage Operation With an Iconoscope Television Camera

By EDWIN C. FRITTS

A heavy-duty 16mm projector was described in 1950 by the author.[1] This projector has since been modified to adapt it to full-storage operation with a television camera. The modifications include a somewhat faster pulldown operating at the uniform rate of 24 frames/sec and a relay condenser system which, in combination with a special shutter and filters, provides adequate illumination of improved quality within blanking time. Operational facilities are also described. The accommodation problem of converting 24 frames/sec of motion pictures into 30 frames/sec for television is treated in an Appendix to the paper.

A PROJECTOR for presenting motion pictures on a screen illuminates the screen for as long a period as possible while allowing the minimum of time for film advancement. In full-storage operation with an iconoscope in a television camera the procedure is reversed. The film is illuminated for only the brief period of vertical blanking, when no image is seen, and the image is stored as an electrostatic charge on the mosaic. The mosaic is dark as it is scanned. Thus, the greater time of the scanning intervals is available for the advancement of the film. However, an element of incompatibility exists between the 24 frames/sec of motion pictures and the 30 frames/sec of television which can be met in either of two ways. By changing the phase of alternate pulldown actions, they can all be made to center on the television fields in the so-called 2–3–2 sequence, and the length of pulldown can fill the greater part of a field. Or, if the pulldown is made shorter than one-half a field, by an amount sufficient to take care of all the necessary tolerances, the uniform 24-frames/sec sequence can be fitted between the blanking intervals (see Appendix).

The projector to be discussed is a modification of the Eastman 16mm Projector, Model 25, which the author has previously described.[1] Let us consider first the basic modifications of this projector to meet the functional requirements as applied to its use in television. Then we will discuss the operational problems and, without too much detail, the means of meeting them.

Presented on May 1, 1951, at the Society's Convention at New York, N. Y. by E. C. Fritts, Camera Works, Eastman Kodak Company, Rochester, N. Y.
(Revised manuscript received on June 8, 1953.)

Fundamental Principles

These include: (1) a pulldown to operate at the uniform rate of 24 frames/-sec and yet dodge the vertical blanking intervals, (2) the unique problem of the shutter and optical system as described, (3) the proper quality of the light for best response from the iconoscope and (4) a modification of the projection objective to work at a 1 to 12 magnification.

The Pulldown. This projector makes use of the shorter pulldown operating at the uniform rate of 24 frames/sec. Certain tolerances are necessary in the accommodation of this pulldown within the scanning time, or, more exactly, to dodge the transmission time of the shutter, which itself is contained within the blanking interval. These include phasing tolerance, tolerance in the adjustment of the pulldown to the shutter at the time of installation, and an allowance for framing, since framing alters the position of the pulldown with respect to the shutter. Reference is made in the original paper to the tuning of the coupling system between the intermittent and its individual motor. This tuning is adjusted, in the case of the television projector, to reduce the time of pulldown action to the required value.

The Shutter and Optical Systems. These items are considered together because of the unique problem inherent in such a projector. The angle of the shutter necessary to occult the optical system is always to be considered in the design of a shutter and optical system. The problem is unique in this case because of the very short time available for exposure. Should a shutter of the proper speed of 60 rps be placed in the position ordinarily used, that is immediately behind the gate, the occulting angle would equal approximately the total available angle of transmission and leave little or no angle for an opening in the shutter.

To meet this condition, we must reduce the diameter of the cross section of the light beam or use a larger shutter, or both. The use of a relay optical system makes it possible to contain the light in a small aerial image of the filament. This image is also formed to the rear of the mechanism, in the normal position for the lamp filament, which provides clearance for a large shutter. Thus, the efficiency of the shutter is raised to where sufficient illumination is obtained from a 1000-w, 10-hr lamp.

Grimwood and Veal[2] have found that the response characteristics of the iconoscope are improved if the quality of the radiation from a tungsten source is altered, particularly to remove a portion of the spectrum in the red and infrared. Filters are placed in the optical system for this purpose.

The projection lens must image the film at a 1 to 12 magnification. The lenses used in the Model 25 were described by Schade.[3] A 4-in. lens of this design is fitted with a compensator which essentially permits the basic objective to occupy the exact position it would be in when projecting onto a distant screen without the compensation. Thus the excellent corrections are preserved.

Operational Conditions

We now consider those features of the projector which pertain specifically to the problem of manipulation. These include: (1) arrangement of parts to fit into a multiplexing combination of more than one projector for one television camera, (2) the separate shutter motor, (3) controls for remote operation, (4) controls to assure proper phasing of shutter to vertical blanking and of the pulldown to the shutter, (5) still-picture operation and (6) the special preamplifier.

Arrangement of Parts. A mirror is generally placed between the projection objective and the iconoscope for multiplexing, and the mounting of this mirror comes close to the front of the projector. Hence it is necessary to move the film reels backwards from their position on the Model 25, as will be seen in Fig. 1. The 4-in. lens is used to provide an optical system of sufficient length for the necessary clearance.

Separate Shutter Motor. The separation of the mechanism of the Model 25 Projector into two completely independent units with separate synchronous motors is the main reason for the low noise and flutter and long life of the mechanism. For the same reasons the shutter of the television modification is driven by a separate three-phase synchronous motor running at 3600 rpm. The greater speed and larger moment of inertia of this shutter and the requirement for greater stability have determined the choice of the three-phase operation and the generous size of the motor. When synchronous motors are linked to large moments of inertia, as is the case with this shutter, the limiting factor in the size of the motor is its capacity to pull the shutter mass into synchronism. A three-phase motor permits starting without an internal switch and is more stable in operation than a single-phase motor.

An additional and equally important reason for the separate shutter motor is to shorten the starting and stopping wastage of film by letting the heavy shutter system coast to a stop independent of the mechanism which stops much more rapidly. The time of starting is short because the large torque required for the "pull into synchronism" is available for greater acceleration in starting.

Controls. The requirement of remote operation calls for a more complicated switching system including a number of

Fig. 1. The Eastman 16mm Television Projector Model 250

relays. This will not be described in detail. It provides for a rather flexible adjustment to studio conditions, for operation from the projector and the monitor positions and includes a douser and provision for still pictures.

Phasing. Two elements of phasing are involved: (1) the shutter opening must occur at the vertical blanking time and (2) the pulldown must dodge this open time.

The motors are all of the salient pole type. Because of the two possible magnetic polarities on the poles of the rotors, they can occupy either of two positions in rotation with respect to the waveform of the power supply, 180 electrical degrees apart. For the two-pole shutter motor, this separation represents 180 mechanical degrees, while the four-pole mechanism motor shifts 90 degrees and the pulldown motor shifts 72 degrees, if the polarity is reversed. Once the pulldown is adjusted to miss the shutter openings, the reversal of polarity in the mechanism motors is of no consequence when the short pulldown is used. With the longer 2–3–2 action these motors would need to be phased at each starting. This problem is treated in more detail in the Appendix.

The shutter opening must occur at the time of vertical blanking. Accordingly, on installation, it must be adjusted in rotation with respect to the motor rotor until this is true. In operation, the choice of polarity of the rotor is necessary to have the exposure occur properly during blanking time rather than as a "shutter bar" in the middle of scanning. This choice is made each time the motor starts. The intelligence for this choice is a half-wave rectified power supply. A commutator on the motor shaft closes two contacting brushes once per revolution. This contact occurs either at the peak of the half-wave voltage or midway in the blocking period of the rectifier when no voltage occurs. In the former case, a pulse of current closes a relay which momentarily opens the motor circuit, causing it to slip a pole. Then the contact will occur at the time of no voltage, and the phasing is correct. When the "On" button is pressed, a motor-driven switch operates through a 4-sec sequence which actuates a solenoid to bring the brushes into momentary contact and then removes them. Phasing is accomplished during this time. This same switch changes the lamp from a standby low voltage to operational voltage. The resulting slow switching of the lamp has much to do with contact life of the switch. Pressing the "Off" button rotates the switch to the off position.

Still-Picture Projection. Another advantage of a separate shutter motor is in the projection of a single frame. Since most of the infrared is removed from the radiation by filters, a single frame can be projected indefinitely. While the shutter is running, the lamp can be operated at normal voltage, and the projector may be interchanged between still and motion projection by merely starting and stopping the mechanism.

Preamplifier. The photoelectric cell feeds into a special preamplifier with a maximum output of 14 dbm. The equalization curves are shown in Fig. 2. The output transformer has a choice of impedance of 75, 150, 300 or 600 ohm.

This projector known as the Eastman 16mm Television Projector Model 250 is designed, as is the Model 25, for long life, high-quality operation and low noise, both mechanical and electrical. The control system, while of necessity more complicated than in the Model 25, is easily accessible for servicing. Troublesome elements are avoided throughout as far as possible, particularly where they might not be readily accessible. The absence of enclosed starting switches in the motors is such a case. Also, the shutter motor

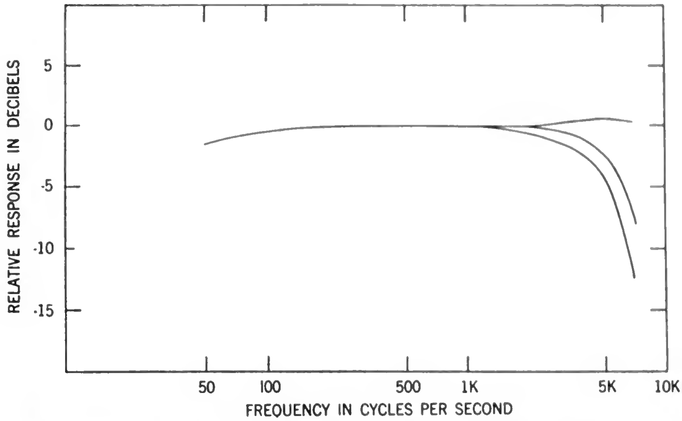


Fig. 2. The audio-response characteristics of the projector.

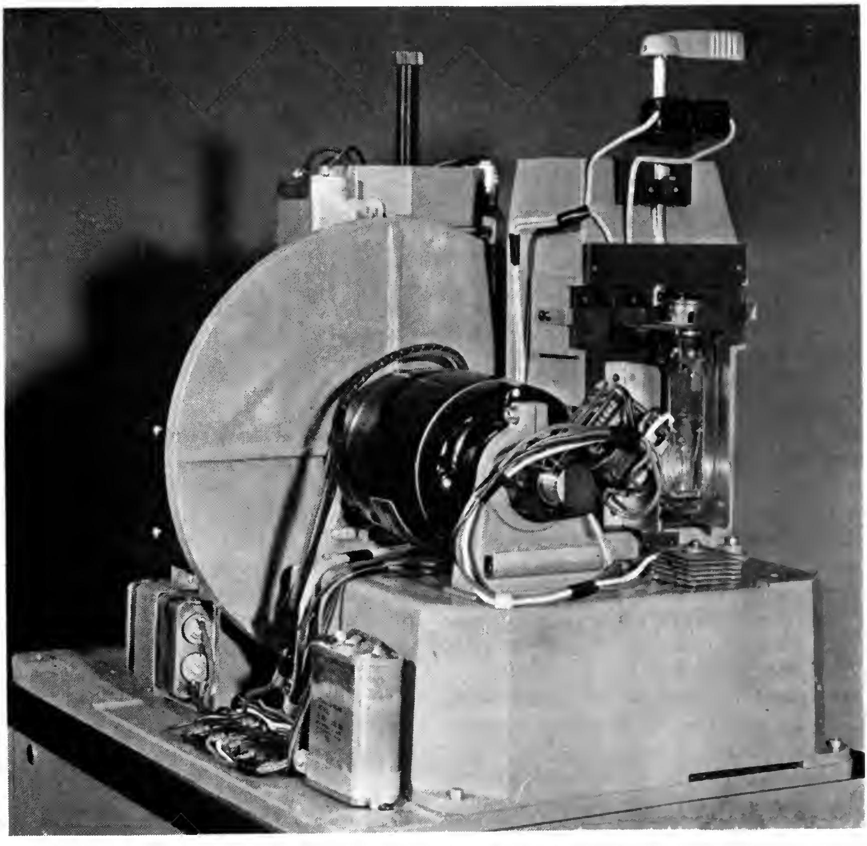


Fig. 3. Rear view of exposed mechanism.

has no winding on the rotor. This avoids a d-c power supply, the collector ring and the winding itself. A failure of any of these would disable the motor. Rather, the phasing mechanism is all external to the motor, simple, and easily accessible for servicing. Figure 1 shows the general view of the projector. Fig. 3 shows the rear view with case removed.

References

1. E. C. Fritts, "A heavy-duty 16mm sound projector," *Jour. SMPTE, 55:* 425–438, Oct. 1950.
2. T. G. Veal and W. K. Grimwood, "Use of color filter in a television film camera chain," *Jour. SMPTE, 57:* 259–266, Sept. 1951.
3. W. E. Schade, "A new $f/1.5$ lens for professional 16mm projectors," *Jour. SMPTE, 54:* 337–344, Mar. 1950.

APPENDIX

The accommodation of 24 frames/sec for motion pictures to 30 frames, 60 fields/sec for television presents a difficult problem in the application of motion pictures to television. Less than 1 msec is available for film movement if the conventional motion-picture practice is followed of advancing the film when no picture information is presented. Such a rapid pulldown would involve, as a general observation, fifty times the magnitude of forces as occur in a 60° pulldown used in motion-picture projection.

In projecting into an iconoscope of a television camera, a dodge of this problem is followed. The exposure is made when picture information is not presented, that is, during vertical blanking time. The iconoscope will remember the exposure as an electrostatic image which is removed during scanning to produce the picture signal. Thus, we have the whole scanning time in which to advance the film. This time is quite ample except for the 24-frame and 30-frame relationship.

Let us consider this relationship. The greatest common denominator of 1/24 and 1/30 is 1/120. 1/120 sec is equivalent to half a television field. 1/24 sec is equivalent to 5/2 a television field, 1/30 sec is equivalent to 4/2 a television field, and 20 half-fields is the minimum number to contain an integral number of both motion-picture frames and television frames.

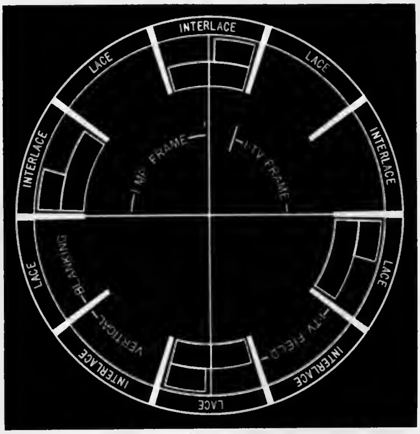


Fig. 4. Motion-picture and television relationship.

Figure 4 shows a circular chart of ten fields. Since half-fields are a common denominator in this scheme of things, a pulldown which takes place in less than a half-field, or 1/120 sec, and at a regular interval of 1/24 sec, can be so phased on our chart as always to miss the blanking time when the exposure is made. The four outermost and smaller boxed segments on our chart represent such a placement of pulldown actions. The larger outlined segments represent a so-called 2–3–2 pulldown sequence. This sequence, it will be seen, is alternately spaced by two fields and three fields. Either sequence misses the blanking times. Thus motion pictures can be projected into television on a storage basis at the uniform rate of 24 frames/sec if the pulldown actions occupy less than half a field. Or, the lengths of pulldown may be approximately twice this length if alternate actions are spaced by two and three television fields, that is by 2/60 sec and 3/60 sec. The average of 2/60 and 3/60 equals 1/24.

We should also observe a difference between these two types of action when the phase of either is shifted one-half a field with respect to the blanking-time sequence. Such a shift is the result of a reversal of polarity in the rotor of a synchronous motor. In the case of the shorter regular sequence, they will always miss while the longer 2-3-2 sequence will fall astride the blanking times if the phase is shifted one-half field from that shown in the chart.

Thus the 2-3-2 sequence requires that the polarity of the motor driving the pulldown be always the same, while this is of no significance with the shorter and uniform 24-cycle sequence.

Errata

George R. Groves, "Progress Committee Report," *Jour. SMPTE, 60:* 535–552, May 1953.

In preparing final proofs, under the subheading "Film Processing Laboratories," a regrettable wrong transposition and error were perpetrated. The fifth and sixth paragraphs of that section should have begun with the following information, respectively:

Consolidated Film Industries constructed a new laboratory building to be used exclusively for 16mm processing and printing . . . ."

"*General Film Laboratories* was a new entry into the independent laboratory field, having taken over the former Paramount facility. . . ."

1953 (Issue No. 2) SMPTE Television Test Film: Operating Instructions

PURPOSE

The Television Test Film is intended to provide a means by which performance tests of a television film reproduction system can be made on a routine operational basis. Its test sections are chosen to emphasize errors of physical alignment and electrical adjustment in such a way that needed corrections become apparent. It is suggested that the reel be run through all projection equipment at regular intervals to provide a standardized indication of normal operation. In this way equipment malfunction may be detected before its effect becomes serious.

This film is not intended to be a laboratory instrument, although it may be useful in product designing and testing.

CONTENTS

Six test sections and a selection of scenes comprise the complete film, which is available in either 16mm or 35mm widths. The test sections are geometrical patterns intended to present information on the factors most likely to be degraded in television film reproduction. Each chart selects some particular failing of the average system and produces a signal intended to exaggerate and thus clearly define any deviation from normal operation. Perfect reproduction of all the charts is to be desired, but some degradation of each is to be expected. Experience will show the magnitude of these effects which may be considered normal for any particular system.

Scenes representative of many types of pictures encountered in television films are included in the reel as a final qualitative test of overall results.

Sec. 1. Alignment and Resolution (See Fig. 1)

This pattern defines the portion of the projected film frame which is to be reproduced by the television system, permitting accurate alignment of the motion-picture projector with the television camera. Eight arrow points have been positioned to touch the edges of the picture area to be scanned. This

---

On January 23, 1953, a meeting of the Films for Television Committee was called by Dr. Raymond L. Garman, Chairman, for the purpose of reaching a decision on a number of changes in the television test film which had been under consideration for some time.

Agreement was reached on changes modernizing the main title, changes in the wording of some section target titles, changes in length of revised sections, elimination of the 1–3–1 step gray-scale target and lengthening the section showing the target with two seven-step tablets.

It was agreed to accept the compromise proposal on picture size for use in setting the dimensions of the alignment target at the arrow points. This means that for 35mm, the reproduced dimensions will be $0.594 \pm 0.002 \times 0.792 \pm 0.002$ in. which, when reduced by the standard ratio of 2.15, will give a 16mm size of $0.276 \pm 0.002 \times 0.368 \pm 0.002$ in.

Charles L. Townsend presented a new target, combining the alignment and resolution tests, which after careful consideration was approved. The committee gratefully extended its thanks to Mr. Townsend and NBC for their excellent work in preparing this target and for their generosity in making it available to the Society without charge.

These changes have been made in the film, and the operating instructions (originally published in the *Journal* in February 1950, pp. 209–218) revised accordingly.

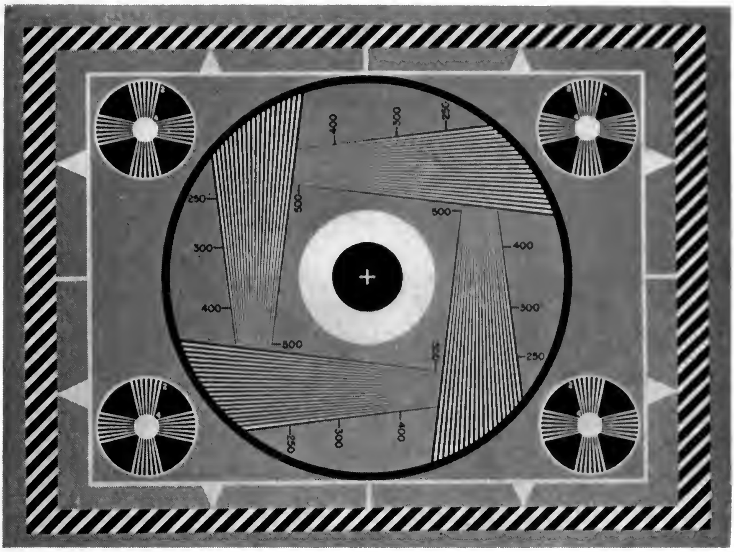


Figure 1

"active area" conforms with a proposed standard developed by a joint RTMA/SMPTE committee representing the industry as a whole. It is intended to be used by producers of films for television as well as broadcasting stations to insure accurate scene-content reproduction. The area outside the arrow points has been striped with a "barber-pole" effect which extends to the limit of the printer aperture. When the projector is positioned correctly and scanning is adjusted perfectly all the picture frame to the arrow tips will be reproduced on the television system, but none of the striped area will show.

It should be noted that the striped area is wider on the sides of the frame than on the top and bottom. This results from the fact that the standard projection aperture does not have a four-to-three ratio but is wider by some 3% (see the American Standards for Picture Projection Apertures, Z22.58-1947 and Z22.8-1950). It may be necessary in some 35mm projectors to enlarge the projection aperture vertically to show some barber-pole across both the top and the bottom of the picture. This is advisable to allow for small scanning irregularities and centering drifts without loss of active picture area. When such irregularities are encountered, size and centering controls should be adjusted to reproduce as much of the "active area" as possible even though some barber-pole may be reproduced. Experience will dictate what compromise settings are required by opposing drift and picture-loss considerations.

At the base of the arrow heads is a white line forming a rectangle which defines a 5% border around the active area. That is, the lines at the top and bottom are placed in from the edges by 5% of the height, and the lines at the sides are placed in from the edges by 5% of the width. These dimensions permit rough estimates of the magnitude of scanning irregularity or misalignment through visual comparison of the effects in question with the size of the border. Specific values for misalignment obtained in this manner can be logged

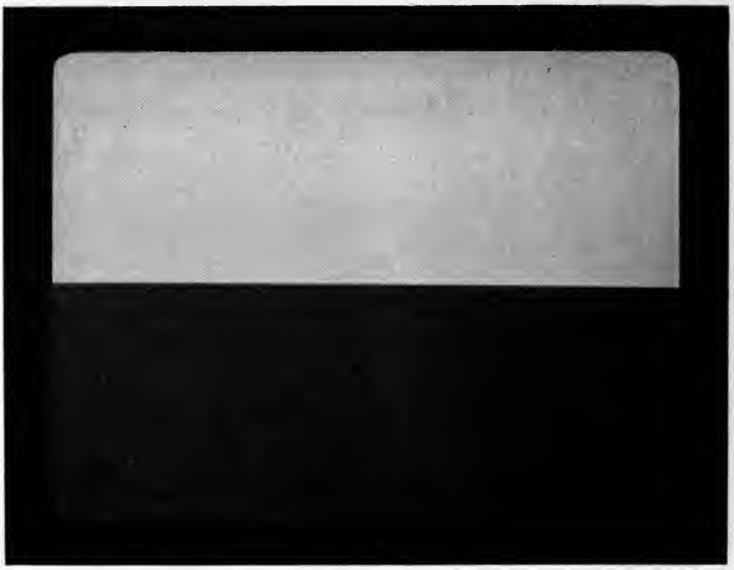


Figure 2

easily for future reference as part of a quality-control program.

White lines are provided in the center of each edge, and a cross is located in the exact center of the pattern to aid in alignment of the optical pattern on the pickup-tube plate.

A gross estimate of scanning-distribution errors can be obtained by observing the "roundness" of the large circle. Localized errors will show up as deformations of the small central circles or those in the corners of the pattern. Observations of this sort require a carefully calibrated picture monitor to insure that all defects noted are in the film-scanning system and not in the picture monitor. It should be noted that the arrows are equally spaced with respect to the corners and center lines. When scanning defects are noted, a ruler laid along the calibrated monitor picture will indicate the place and size of the scanning error.

Overall system resolution is indicated by the converging line wedges in the pattern. By noting the point at which the individual lines making up the wedges are no longer visible separately, an estimate of the value of system resolution can be made from the calibration adjacent to that point. The calibrations are in television system lines. The small corner wedges are marked in hundreds of television lines. These wedges may be used for checks of both optical and electrical focus.

Sec. 2. Low-Frequency Response (See Fig. 2)

This test is made in two parts, each consisting of a half-black/half-white frame, with the dividing line horizontal. The first section has the black portion at the top of the frame and the second is black at the bottom. These charts produce 60-cycle square-wave signals. When viewed on the waveform monitor set for field-rate deflection, the signals should appear reasonably square. Serious tilting or bowing indicates incorrect low-frequency phase and amplitude response. When the system has been set for reproducing the first chart, the

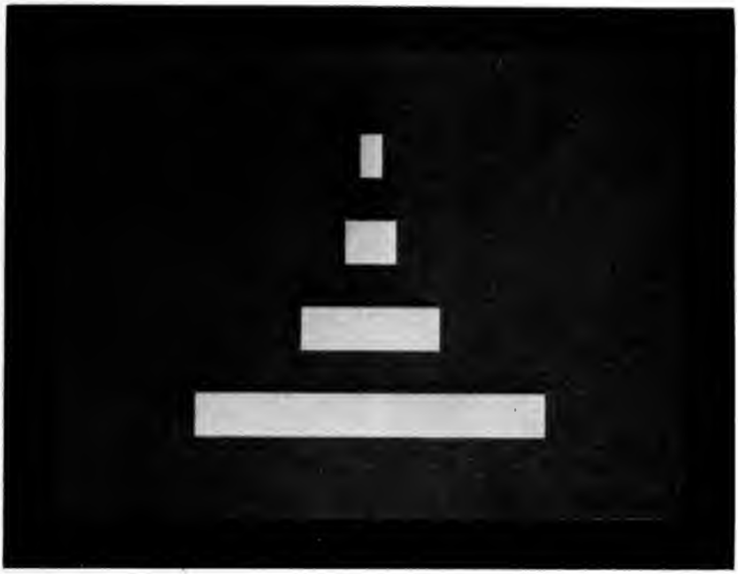


Figure 3

change to the second chart should not necessitate large shading changes.

The chart which is black at the bottom also permits a check on the amount of flare encountered in iconoscope operation. Rim lights and beam current should be reset if the flare is excessive.

Sec. 3. Medium-Frequency Response (See Fig. 3)

The response of the television system to medium-frequency signals is of importance to picture quality. In this test, horizontal bars are used, first as black on white and then reversed. The bars have lengths equal in time of scanning-beam travel to 2, 5, $12\frac{1}{2}$ and 32 microseconds. These correspond to half-wave pulses covering an approximate fundamental frequency range from 15 to 250 kilocycles. Correct medium-frequency phase and amplitude response will be indicated by leading and trailing edges of the bars having no long, false gray tones. If, following the trailing edge of a bar, a streak appears having a tone similar to that of the bar (white after white, black after black), then it is reasonable to assume that the amplitude of the frequency represented by that bar is too great, or that its relative phase is incorrect. If the opposite occurs, as a white streak after a black bar, the fundamental frequency is too low in amplitude, and its relative phase is in error.

Sharp transient effects immediately following all bars are an indication of excessive high-frequency response. This condition will usually be clearly indicated in the test for resolution.

If very long streaking occurs in which the spurious signals are seen on the left side of the bars, as well as on the right, an investigation of the low-frequency response of the system should be made. Under these conditions close examination of the previous charts should reveal errors of waveform.

It is rarely possible to obtain perfect streaking-free reproductions of both the black-on-white and the white-on-black charts with one setting of the controls. The settings which produce very small

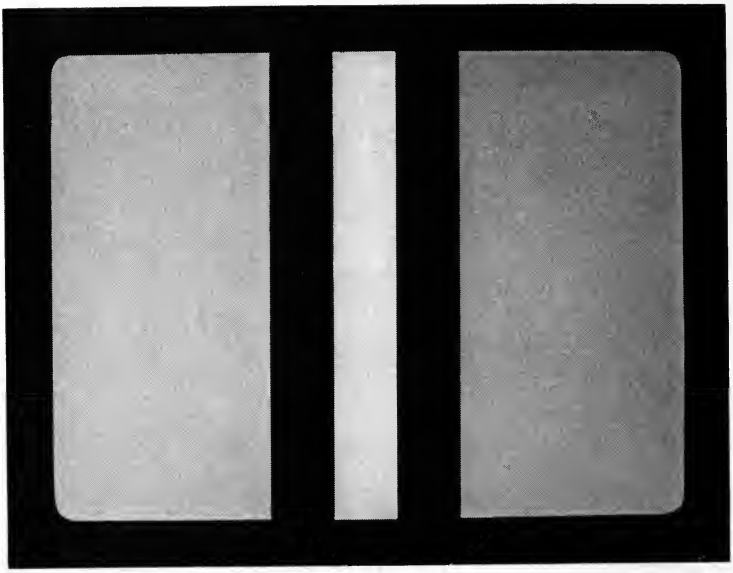


Figure 4

streaking equally on both charts are usually preferred.

Sec. 4. Storage (See Fig. 4)

Film pickup systems which utilize short pulses of light must store the charge produced by the pulse long enough to permit the charge image to be scanned. Since the beam starts the scanning process at the top of the picture, the storage time required is maximum at the bottom of the picture. Some pickup tubes will suffer from leakage to the extent that the charge image may be seriously reduced in amplitude by the time the beam reaches the bottom of the picture.

The chart which checks this characteristic is made up of vertical black and white stripes on a gray background. When viewed on the waveform monitor (set at field rate) this pattern will produce three lines representing white, gray and black. Shading should be set to hold the gray line parallel with the blanking axis. If the white and black lines then tend to converge, the pickup tube does not have perfect storage. Perfect results are indicated when all traces are parallel. If the black-to-white amplitude at the bottom of the picture is divided by that at the top of the picture, the tube's storage factor is obtained. This is usually expressed in percentage.

Sec. 5. Transfer Characteristics (See Fig. 5)

The ability of a television system to reproduce shades of gray is indicated in this section through the use of step-density areas. The chart consists of two step-density tablets showing seven steps each. The direction of progression of the second tablet is opposite to that of the first to provide maximum values at each side of the picture frame.

The neutral gray background of this chart should be shaded flat, and gain and brightness settings should be adjusted to give normal waveform-monitor amplitudes. Under these conditions each step should be visually compared with the adjacent steps, both in the

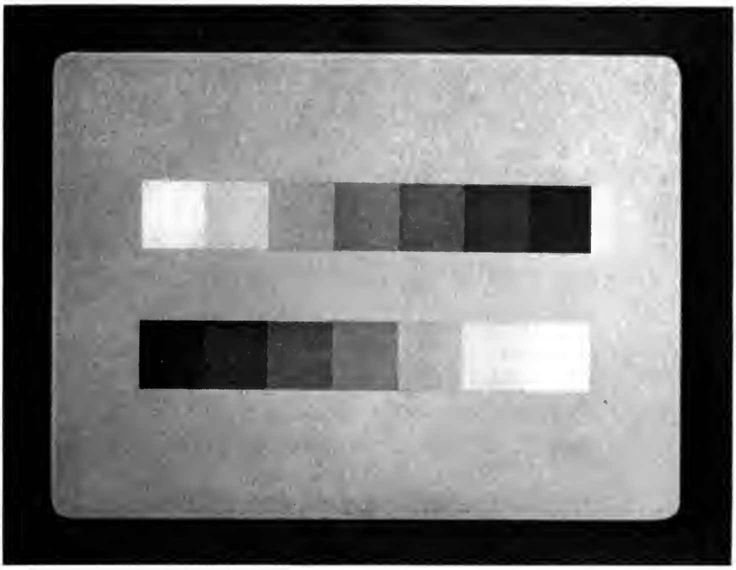


Figure 5

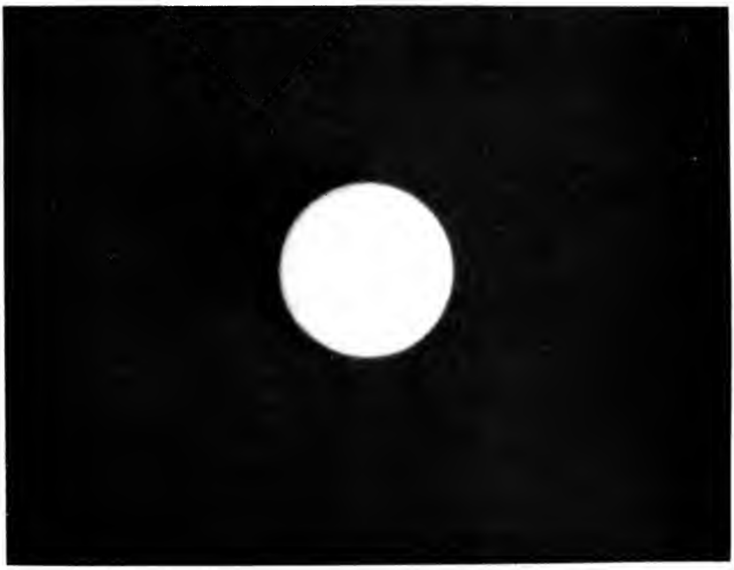


Figure 6

Figure 7

picture and on the waveform monitor, and each should be clearly defined. Compression effects will be seen as a cramping together of adjacent steps. Experience as to the appearance of the tablets will establish a norm from which variations can be noted.

The effective transfer characteristic of a film-pickup system is a function of both film density and projected illumination. This test film has a range considered to represent that normally encountered in practice. If significant compression occurs, projector brightness should be checked. Other factors, including beam current, bias-light, and clipper adjustments should be tested with a stationary slide.

Sec. 6. Automatic Brightness Control (See Fig. 6)

This test indicates the ability of the television system to follow changes in average illumination of a series of scenes. It consists of a white disk centered in a black frame which enlarges slowly to fill the whole frame. As the white portion becomes larger, the brightness control should hold the black level constant. On the waveform monitor, the black signals should remain fixed, in position relative to the blanking level. The first brightness changes on the film are both slow and even, so that systems with slow-acting control should be able to follow them accurately.

The second portion of the test consists of sudden changes in white disk size from the smallest size to one third of the frame area and then to two thirds of the frame area. Experience will show how much error in black-level setting results in these cases on a transient basis.

Sec. 7. Typical Scenes (See Fig. 7)

To provide a qualitative check on the overall results to be expected from good film, several scenes taken from material used specifically for television are included in the test reel. Utilization of this section will depend upon the operator's experience in judging acceptability and upon his memory of "how they looked before."

Two Proposed American Standards—PH22.95, PH22.96

Television Picture Area—35mm and 16mm Motion-Picture Film

Two proposed American Standards on 35mm and 16mm television picture area are published on the following pages for 3-month trial and criticism. All comments should be sent to Henry Kogel, Staff Engineer, prior to November 1, 1953. If no adverse comments are received, the proposals will then be submitted to ASA Sectional Committee PH22 for further processing as American Standards.

The two proposals are consistent with existing standards for camera and projector apertures, with one exception. The standard 35mm projector aperture was considered unsatisfactory for television use because its aspect ratio is not 4 by 3 and because its specified height results in a loss of picture area that was considered by many to be excessive. The present proposal increases the height of the 35mm projector aperture as much as possible without requiring enlargement of the 16mm projector aperture, thus permitting reproduction of optical reduction prints. Enlargement of the 35mm aperture is considered permissible because the number of 35mm projectors now in television use is not great and because the construction of 35mm equipment makes alteration or replacement of the aperture a very simple matter. —*F. N. Gillette*, Chairman, Television Film Equipment Committee.

Proposed American Standard

Television Picture Area—35mm Motion-Picture Film

(Third Draft)

PH22.95

1. Scope

1.1 The area to be included in a television picture is determined at the point of origination of the program concerned. In subsequent treatment of the resulting picture, it is very important that excessive cropping of the edges of the picture be avoided. The purpose of this Standard is to establish operating procedures which will minimize the loss in area sustained in recording a television picture on 35mm film and in subsequently reproducing the film with a television film chain, and also to prevent the televising of a black or white band formed by the edge of the recorded area or the projector aperture.

1.2 Since the film chain equipment will also be used, without intervening readjustment of the equipment, for reproduction of films produced by standard photographic techniques, the Standard provides for optimum utilization of the picture area of standard 35mm motion-picture film.

1.3 Film prepared by conventional photographic techniques for television reproduction shall be prepared in accord with the provisions of Z22.59–1947, Photographing Aperture of 35mm Sound Motion Picture Cameras, or the latest revision thereof, approved by the American Standards Association, Incorporated, which specifies the location and size of the camera aperture. The loss of significant picture information in television reproduction can be avoided by providing in the camera viewfinder an indication of the area to be scanned in television reproduction.

1.4 Paragraph 2 of this Standard applies only to video recordings intended for reproduction by a television system. If the video recording is intended for direct projection to a theater screen the image dimensions, with the exception of picture width, are adequately specified by American Standard Z22.59–1947, or the latest revision thereof. For the correct aspect ratio the image width should be 0.841 ± 0.004 inch.

2. Video Recording on 35mm Motion-Picture Film

2.1 The picture aperture of a 35mm television recording camera shall be in accord with American Standard Z22.59–1947, or the latest revision thereof.

2.2 The television picture appearing on the picture tube of the video recording equipment shall produce an image on the recording film having a height of 0.612 ± 0.004 inch and a width of 0.816 ± 0.004 inch.

2.3 The center point of the image shall coincide with the center point of the picture aperture of a 35mm motion-picture projector as specified by American Standard Z22.58–1947, Picture Projection Aperture of 35mm Sound Motion Picture Projectors, or the latest revision thereof, approved by the American

NOT APPROVED

Standards Association, Incorporated. (This actually serves to locate the image relative to the film.)

3. Television Reproduction of 35mm Motion-Picture Film

3.1 Except for height and width dimensions the picture aperture of a 35mm television projector shall be in accord with American Standard Z22.58–1947, or the latest revision thereof. The height dimension shall be 0.612 ± 0.002 inch and the width dimension shall be 0.816 ± 0.002 inch.

3.2 The portion of a 35mm motion-picture film reproduced by a television film chain shall be an area having a height of 0.594 ± 0.004 inch and a width of 0.792 ± 0.004 inch.

3.3 The center point of the reproduced portion of the film shall coincide with the center point of the picture aperture of a 35mm motion-picture projector as specified by American Standard Z22.58–1947, or the latest revision thereof. (This actually serves to locate the reproduced area relative to the film.)

NOT APPROVED PH22.95

Proposed American Standard

Television Picture Area—16mm Motion-Picture Film

(Third Draft)

PH22.96

1. Scope

1.1 The area to be included in a television picture is determined at the point of origination of the program concerned. In subsequent treatment of the resulting picture, it is very important that excessive cropping of the edges of the picture be avoided. The purpose of this Standard is to establish operating procedures which will minimize the loss in area sustained in recording a television picture on 16mm film and in subsequently reproducing the film with a television film chain, and also to prevent the televising of a black or white band formed by the edge of the recorded area or the projector aperture.

1.2 Since the film chain equipment will also be used, without intervening readjustment of the equipment, for reproduction of films produced by standard photographic techniques, the Standard provides for optimum utilization of the picture area of standard 16mm motion-picture film.

1.3 Film prepared by conventional photographic techniques for television reproduction shall be prepared in accord with the provisions of American Standard Z22.7–1950, Location and Size of Picture Aperture of 16mm Motion Picture Cameras, or the latest revision thereof, approved by the American Standards Association, Incorporated, which specifies the location and size of the camera aperture. The loss of significant picture information in television reproduction can be avoided by providing in the camera viewfinder an indication of the area to be scanned in television reproduction.

1.4 Paragraph 2 of this Standard applies only to video recordings intended for reproduction by a television system. If the video recording is intended for direct projection to a theater screen the image dimensions are adequately specified by American Standard Z22.7–1950, or the latest revision thereof.

2. Video Recording on 16mm Motion-Picture Film

2.1 The picture aperture of a 16mm television recording camera shall be in accord with American Standard Z22.7–1950, or the latest revision thereof.

2.2 The television picture appearing on the picture tube of the video recording equipment shall produce an image on the recording film having a height of 0.285 ± 0.002 inch and a width of 0.380 ± 0.002 inch.

2.3 The center point of the image shall coincide with the center point of the picture aperture of a 16mm motion-picture camera as specified by American Standard Z22.7–1950, or the latest revision thereof. (This actually serves to locate the image relative to the film.)

3. Television Reproduction of 16mm Motion-Picture Film

3.1 The picture aperture of a 16mm television projector shall be in accord with American Standard Z22.8–1950, Location and Size of Picture Aperture of 16mm Motion Picture Projectors, or the latest revision thereof, approved by the American Standards Association, Incorporated.

NOT APPROVED

3.2 The portion of a 16mm motion-picture film reproduced by a television film chain shall be an area having a height of 0.276 ± 0.002 inch and a width of 0.368 ± 0.002 inch.

3.3 The center point of the reproduced portion of the film shall coincide with the center point of the picture aperture of a 16mm motion-picture projector as specified by American Standard Z22.8–1950, or the latest revision thereof. (This actually serves to locate the reproduced area relative to the film.)

NOT APPROVED **PH22.96**

CORRECTION — PH22.53-1953

Method of Determining Resolving Power of 16mm Motion-Picture Projector Lenses

This American Standard, last published in the May 1953 *Journal*, is reprinted on the two following pages, with typographical corrections made in paragraph 2.1.1 and in the first line of the Note directly under the title of Fig. 3.

AMERICAN STANDARD

Method of Determining Resolving Power of 16mm Motion-Picture Projector Lenses

ASA
Reg. U. S. Pat. Off.

PH22.53–1953

Revision of Z22.53–1946
*UDC 778.55

1. Scope

1.1 This standard describes a method of determining the resolving power of projection lenses used in 16mm motion-picture projectors. The resolving power shall be measured in lines per millimeter.

2. Test Method

2.1 The lens to be tested shall be mounted in a special test projector. A glass plate test object, carrying patterns of lines, shall be then projected upon a white matte grainless screen located at such a distance from the projector that the projected image of the border of the test object measures 30 × 40 inches. The resolving power of the lens is the largest number of lines per millimeter in the test object pattern that an observer standing close to the screen sees definitely resolved in both the radial and tangential directions. Lines shall not be regarded as definitely resolved unless the number of lines in the image is the same as the number of lines in the test object.

2.1.1 The patterns of lines shall consist of parallel black lines 2.5/X mm long and 0.5/X mm wide with a clear space 0.5/X mm wide between the parallel lines, where X equals the number of lines per millimeter.

2.2 Care shall be taken to insure that the screen is perpendicular to the projection axis and that the lens is focused to give the maximum visual contrast in the fine detail of the central image.

3. Test Projector

3.1 The projector design shall be such that the glass plate test object is held in proper relation to the lens axis. It shall not heat the test plate to a temperature which may cause the plate to be fractured or otherwise damaged. The emulsion side of the test plate shall be toward the projection lens.

3.1.1 The cone of light supplied by the projector shall completely fill the unvignetted aperture of the test lens for all points in the field. This may be verified by lowering the lamp voltage and looking back into the projection lens through holes in the projection screen situated at the stations A, B, C, etc. It can then be easily seen whether the lens aperture is properly filled with light.

4. Test Object

4.1 The glass photographic plate used for making the test object and the lens used in making the reduction of the master test chart shall have sufficiently high resolving power to insure clear definition of all lines in the patterns on the test object.

4.2 The photographic reduction of the master test chart shall be such that the test object border has a height of 7.21 mm (0.284 inch) and a width of 9.65 mm (0.380 inch) with a radius of 0.5 mm (0.02 inch) in the corners, and such that the sets of lines in the reduced image are spaced 20, 30, 40, 50, 60, 80, and 90 lines per millimeter.

Approved April 16, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
ASA½M653

Price, 25 Cents

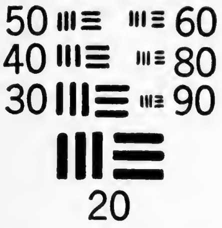


Fig. 1. Resolution Test Patterns (× 100 Diameters).

4.3 The patterns on the test object shall be in accordance with Fig. 1.

4.4 The position of the test patterns on the test object shall be in accordance with Fig. 2.

4.5 Identification of the positions of the test patterns on the test object shall be in accordance with Fig. 3.

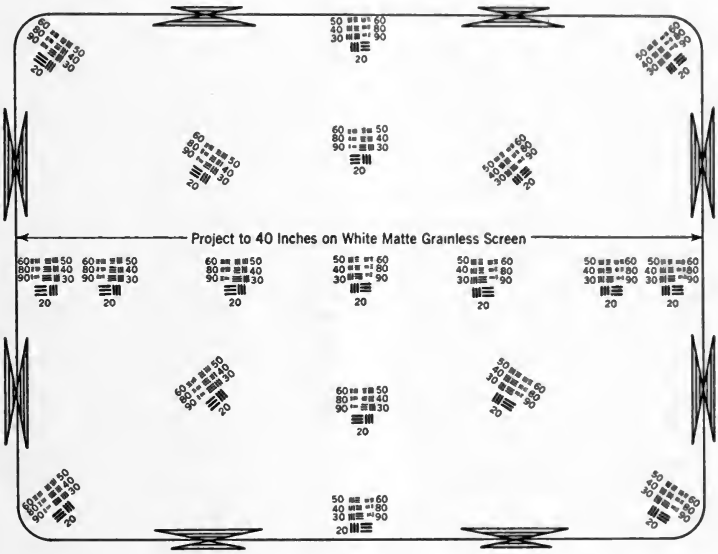


Fig. 2. Resolving Power Test Object (× Approximately 15 Diameters).

Note: The triangular edge patterns are to facilitate alignment of test plates in the projector.

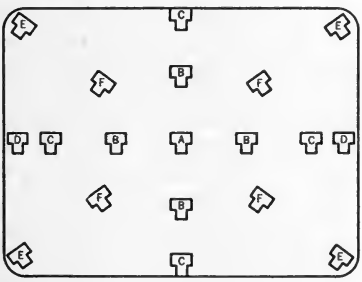


Fig. 3. Identification of Test Patterns in Frame Area.

Note: When using a 2-inch focal length lens, B corresponds to 2 degrees from the axis, C corresponds to 4 degrees from the axis, D corresponds to 5 degrees from the axis, E corresponds to 6 degrees from the axis, and F corresponds to 3 degrees from the axis.

Note: Glass test plates in accordance with this standard are available from the Society of Motion Picture and Television Engineers, 40 West 40th Street, New York 18, N.Y.

PH22.53–1953

1953 Convention of the NEA Department of Audio-Visual Instruction

By D. F. LYMAN

The 1953 convention of the Department of Audio-Visual Instruction of the National Education Association was held in St. Louis, February 24 to 28. This year, with 727 registrants, the attendance was about twice that reported last year.* There were representatives from 42 states, two provinces of Canada, Pakistan, Thailand, the Philippines and Egypt. The writer of this review attended as a representative of the Society of Motion Picture and Television Engineers.

Exhibits

At the suggestion of a number of the members who went to the conference in Boston last year, arrangements had been made to have commercial exhibits in operation during this convention. There were 44 booths and 41 exhibitors. Their displays included the following items: 16mm motion-picture projectors; 35mm still-picture projectors; opaque projectors; details about motion-picture film libraries; sources of 35mm film strips; 16mm reels; tape recorders; printing materials; disc records; library services; room-darkening materials; equipment for handling, marking and storing films; and projection screens.

A report received on March 17, 1953.

* D. F. Lyman, "Audio-Visual Conference," *Jour. SMPTE, 58:* 445–449, May 1952.

Program

Because of the way the conference was operated, the program is a major work in itself. It consists of a 5 × 7½ inch booklet with 41 printed pages. It shows the sequence of preconference and conference meetings, the topics discussed in the separate meetings of the 13 sections, the chairmen and recorders of all the meetings, long lists of "resource leaders" for the section meetings, the exhibitors and the layout of their space, and general information about the convention and the department. The great deal of work which must have gone into the booklet was a worthy effort, for it was one of the chief reasons for the smooth running of the convention.

As at the previous convention, there were a few general sessions for the entire group of registrants, but much of the time was devoted to separate meetings of 13 discussion groups sponsored by national committees or sections. These committees, which are responsible for continual progress in their particular endeavors throughout the following year, receive a great deal of help from the ideas and suggestions expressed in the discussions held during the conventions. Brief reviews of some of the general sessions and section meetings are given below.

General Sessions

The first general session was a presentation of a selected group of films which had been rated as outstanding at recent European film festivals.

At the main dinner meeting, the speaker was R. J. Blakely from the fund for Adult Education of the Ford Foundation. He described the investigations that are being made to determine how television can be applied most effectively in educational work, and the relation of television to other forms of mass communication such as newspapers, films, radio and picture magazines.

In his president's message, J. W. Brown spoke of the continued growth of the DAVI organization, which had 1066 members in 1951, 1381 in 1952, and now has 1755 in 1953.

On Thursday morning, a still-picture film in color was presented with accompanying sound on magnetic tape. It described and showed an experiment conducted in a Cleveland school located in an underprivileged area. Rapid advances were made by children of pre-reading age when audio-visual work on the subject of farms, presented over a period of several weeks, was supplemented by a field trip to a farm. Questions and answers recorded before, during, and after the experiment showed that the pupils made substantial general progress, as well as learning a great deal about farms and farmers.

At this same meeting, Maurice Ahrens spoke on "The Role of Instructional Materials Specialists in Curriculum Development Programs." He outlined the transitions that have taken place in the development of curriculums, from textbooks alone to specialists in that type of work, then to teacher committees, and finally to the more modern method that stresses development of a curriculum to suit each individual school. He emphasized that the materials specialist and the materials laboratory should take a leading role in the operation of this most recent method. He believes that each school should have its own laboratory, but that the work of the individual laboratories should be correlated by a central laboratory, which is in a better position to plan budgets, for example. A materials specialist will find it necessary to work with groups of teachers in order to spread his efforts effectively. Furthermore, he should help with plans for buildings, so that audio-visual aids can be used to their full advantage, work with principals and other consultants and specialists, provide a workshop and a community resource file, and facilitate the use of his materials. The facilities and functioning of such a center were illustrated by a 16mm film based on the school system of Corpus Christi, Texas.

At another general session, a panel of speakers under the chairmanship of F. E. Brooker described some of the international developments in the audio-visual field. Reports were made by DAVI members who have served abroad in the Mutual Security Agency or Point Four organizations. Included was the work done in the Philippines, France, Iran, Israel and India, as well as some of the coordinating work in Washington, D.C. A teacher from the Philippines and a student from Egypt gave further descriptions of audio-visual plans in their countries.

Field Trip to Audio-Visual Center

One of the best features of the convention was the open house at the Audio-Visual Education Building of the Division of Audio-Visual Education for the St. Louis public schools. There was ample opportunity to visit all the departments of this large audio-visual center and to talk with the hospitable members of its staff. In addition to the libraries, museums, laboratories and storage rooms, the building houses station KSLH, an FM radio station being operated as a part of the city's educational system. Sample films to show how local subjects can be kinescoped and photographed for use on educational television programs were shown, respectively, by A. L. Hunter of Michigan State College and John Whitney of the St. Louis schools.

Section Meetings

Of the 13 Sections meeting during the week, Section 8, Buildings and Equipment, which the writer attended, is more closely allied than any of the others with the work of the Society of Motion Picture and Television Engineers. This Section considered a draft of a booklet on Audio-Visual Centers. This is the third to be published. No. 1 is *Classrooms*,* while No. 2, just issued, is *Auditoriums*. Although no final drafts were drawn during the meetings, there was a great deal of discussion about the following points: the scope of the booklet under consideration, ways to insure positive action in securing audio-visual centers, the functions the center must fulfill, how different schools and school systems should be covered, the distinction between an "audio-visual center" and an "instructional materials center," the advantages and disadvantages of providing sample floor plans that would show architects how much space is needed for each function, the respective responsibilities of a coordinating center and a local center, how both types should be administered, how plans can be made for future growth and new materials, the best climatic conditions for "caring for" equipment and materials, and the needs of those who are being called upon to change from a single-system building center to a central system that coordinates the work of a number of building centers. At times, the discussion seemed to show many points of difference, but when it is analyzed, it should be of great assistance to the small group that will write the next drafts of the booklet.

Most of the sections had previously solicited the aid of "resource leaders" who had agreed to serve in that capacity and were called upon for suggestions, That method, and the frequent use of a panel of speakers in the general sessions, serves to enlist the capabilities of experts who otherwise might not be heard. This idea has interesting possibilities. In the case of resource leaders, more specific results could be obtained if each person were assigned — or voluntarily assumed — some particular phase of the work.

* Ann Hyer, "Planning classrooms for audio-visual materials," presented on October 7, 1952, at the Society's Convention at Washington, D. C., and scheduled for early *Journal* publication. *Classrooms* was reviewed in the Sept. 1952 *Journal*, and *Auditoriums* in April 1953.

Theater Survey

The eruption of technical innovations in the production and exhibition of motion pictures has given rise to a certain degree of confusion and hesitation. The last 25 years have witnessed the development of sound and color and the beginnings of theater television. In the space of less than a year the industry has been swamped by Cinerama, 3-D, stereophonic sound, aspect ratios increased from 4:3 to 5:3, $5\frac{1}{2}$:3, talk of 6:3 and CinemaScope $7\frac{2}{3}$:3. These are being advocated singly and in various combinations.

However there are several "unknowns" in these equations. Possibly of major significance is the question of structural limitations. Stated more fully, what shapes and sizes of pictures can be economically exhibited in enough theaters to become the practical basis for future standards? Also vital, is a statistical evaluation of the response of exhibitors to these developments whose adoption necessitates new financial investments. Theater owners, producing companies, equipment manufacturers and dealers, engineers and architects, all are concerned with the answers to these questions.

To secure effectively this desired information the Society's Theater Engineering Committee, with the cooperation of the Motion Picture Research Council, initiated at its last committee meeting, April 30, 1953, a Theater Survey. The complete text of the survey questionnaire is published on the following pages. Distribution of the questionnaire, begun May 25, 1953, was made through the cooperation of the following trade organizations: Motion Picture Association of America, Theater Owners of America, Independent Theater Owners of America, Metropolitan Motion Picture Theaters Association, Allied States Association Theater Owners of America, Theater Equipment Dealers Association; also the following companies: National Theater Supply Company, Altec and RCA Service Companies and several large theater circuits; and also upon request, directly to individual theaters as a result of the wide interest generated through nationwide publicity.

Despite the seemingly haphazard distribution pattern, plans have been made to analyze the returns on a scientific basis giving due weight to such factors as geography, population density, seating capacity, distribution pattern of the different-sized theaters, etc. It is hoped thereby to come up with answers which are applicable industry-wide. After a sufficient number of returns (500 to 1000) are received to build up a valid statistical sample, the survey results will be published as a committee report in this *Journal.* It is expected that this will help eliminate the confusion and hesitation and will provide a firm foundation for many of the important decisions yet to be made.—*Henry Kogel*, Staff Engineer.

May 25, 1953

Theater Screen Survey

With the present great interest in new forms of motion pictures, the producers, the exhibitors and the equipment suppliers are faced with many major decisions. In order that certain of these decisions may be based on facts not now available, the Theater Engineering Committee of the SMPTE is conducting this survey. It is hoped to present the replies from a large cross section of exhibitors in a tabular and graphic summary; individual information will not be publicized.

Since this study is of urgent importance to the whole motion-picture industry, your prompt reply will be appreciated.

The first two questions relate to 3-D pictures by means of the simultaneous projection of two prints for viewing through polarizing glasses:

1. Is your theater already converted for the exhibition of 3-D pictures? Yes______ No______
2. If not, do you plan to convert during 1953? Yes______ No______
3. Have you recently increased the size of your screen to provide for "wide-screen" projection? Yes______ No______
4. If not, do you plan to install a larger screen during 1953? Yes______ No______
5. Seating capacity: Orchestra (main floor) . . . . ______
   Stadium . . . . ______
   First balcony . . . . ______
   Second balcony . . . . ______
   Total seats ________

6. Size of present picture (inside of masking) . . . . Height________ Width________

7. Focal length of projection lens . . . . ________

8. Projection angle, in degrees . . . . ________

9. If location of projection booth differs from that shown in side view, Drawing 2 or 3, please sketch in position of booth, including height of projection port above floor level.

10. Fill in all obtainable dimensions on Diagrams 1 and 2 for theater without balcony, or 1 and 3 for theater with balcony.

11. Indicate any special conditions in your theater:

Best of all, if you have architects' drawings of the main floor plan and the front-to-back cross section of the auditorium, photostats or other copies of them would be of great value to the Committee in making this detailed study.

Name of theater ________________

Address ________________

Name of circuit, if any ________________

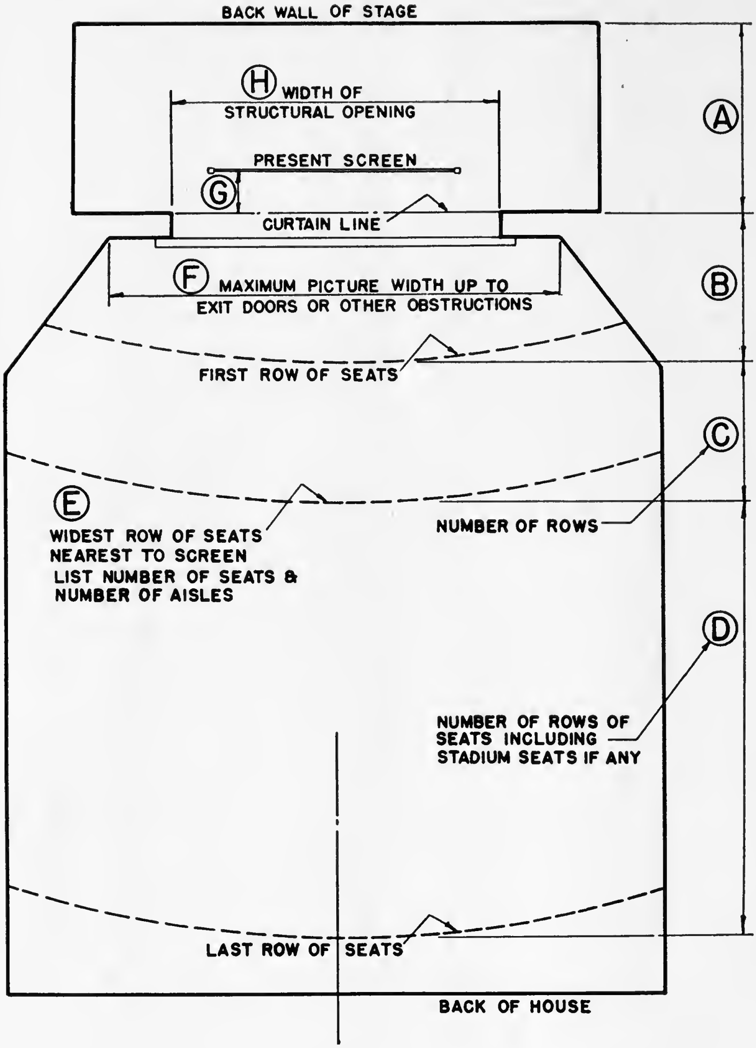
Your name and title ________________

Date ________________

If you want, keep a copy of this questionnaire, but please be sure to return one copy to:

Henry Kogel, Staff Engineer
Society of Motion Picture and Television Engineers
40 West 40th St., New York 18, N.Y.

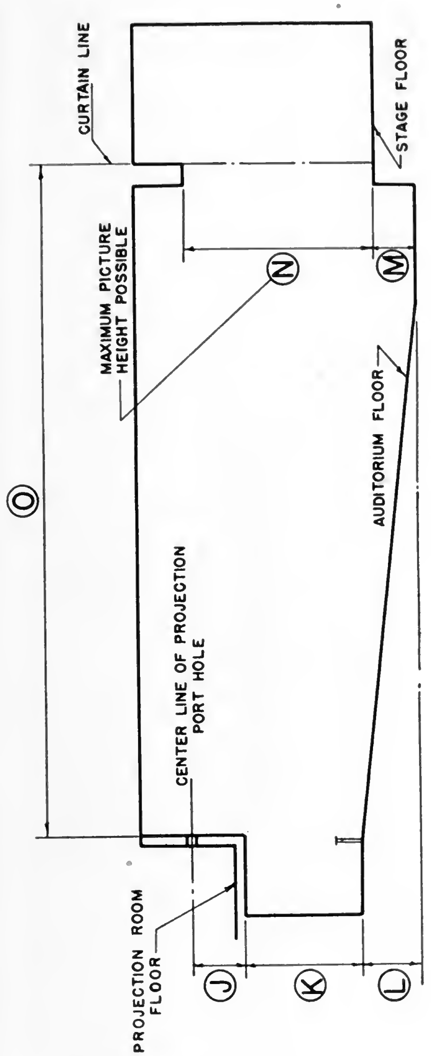
S M P T E Committee on Theater Engineering



ORCHESTRA

A ____________ | ____________ AISLES
B ____________ | F ____________
C ________ ROWS | G ____________
D ________ ROWS | H ____________
E ________ SEATS

DIAGRAM No. 1



SIDE VIEW WITHOUT BALCONY

J ____________ M ____________

K ____________ N ____________

L ____________ O ____________

DIAGRAM No. 2

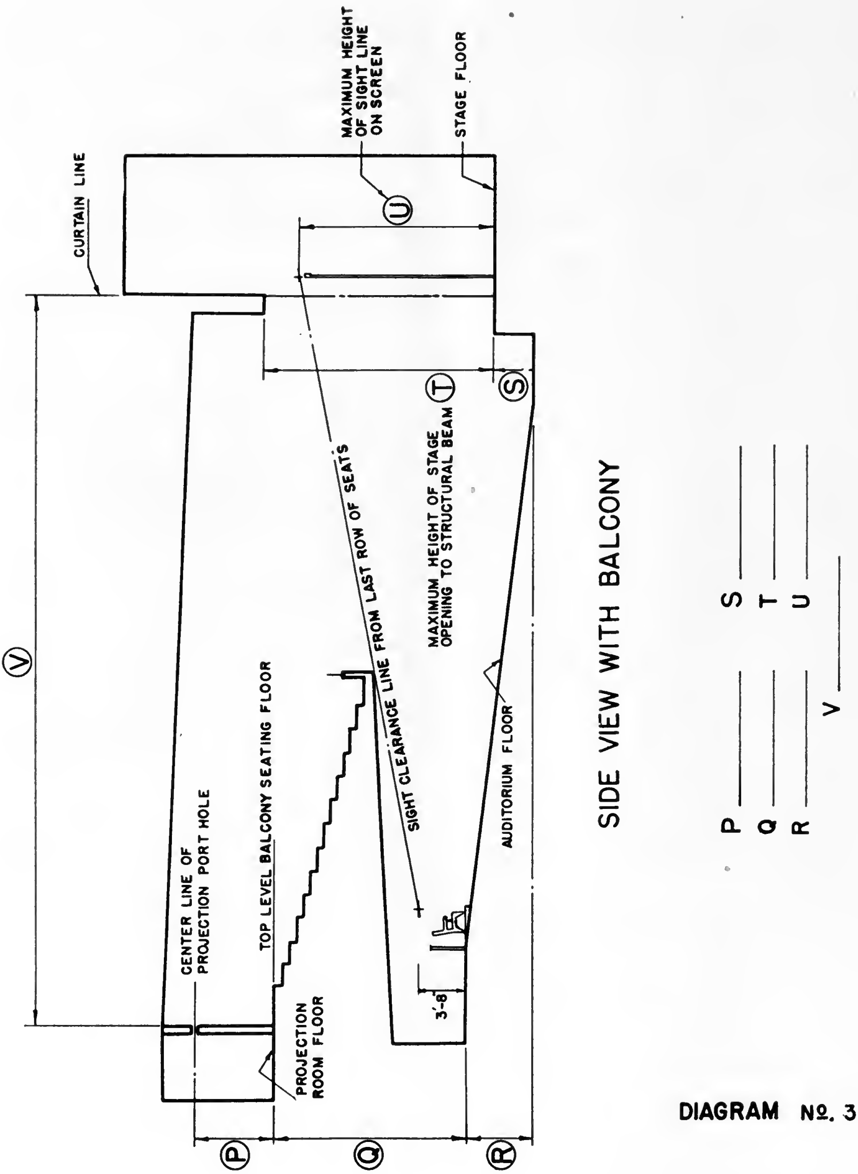

CURTAIN LINE
MAXIMUM HEIGHT OF SIGHT LINE ON SCREEN
STAGE FLOOR
U
T
S
V
MAXIMUM HEIGHT OF STAGE OPENING TO STRUCTURAL BEAM
SIGHT CLEARANCE LINE FROM LAST ROW OF SEATS
CENTER LINE OF PROJECTION PORT HOLE
TOP LEVEL BALCONY SEATING FLOOR
AUDITORIUM FLOOR
3'-8"
PROJECTION ROOM FLOOR
P
Q
R
SIDE VIEW WITH BALCONY
P ____ S ____
Q ____ T ____
R ____ U ____
V ____

DIAGRAM No. 3

74th Convention

On October 5–9 at the Hotel Statler in New York will be presented a program of technical papers now being assembled by Skip Athey. If you have, or know about, a subject which should be on the program, wire or telephone anyone on the list below or anyone on the Papers Committee roster given in the April *Journal*. A substantial number of papers is already arranged, but no worthy paper is as yet too late.

Chairman: W. H. Rivers, Eastman Kodak Co., 342 Madison Ave., New York 17.
74th Program Chairman: Skipwith W. Athey, c/o General Precision Laboratory, 16 South Moger Ave., Mt. Kisco, N.Y.
For Washington: J. E. Aiken, 116 No. Galveston St., Arlington 3, Va.
For Chicago: Geo. W. Colburn, 164 N. Wacker Dr., Chicago 6, Ill.
For Canada: G. G. Graham, National Film Board of Canada, John St., Ottawa, Canada
For 74th Convention High-Speed Photography: Charles A. Jantzen, Photographic Analysis Co., 100 Rock Hill Rd., Clifton, N.J.
For Hollywood: Ralph E. Lovell, 2743 Veteran Ave., West Los Angeles 64, Calif.
For High-Speed Photography: John H. Waddell, 850 Hudson Ave., Rochester 21, N.Y.

Membership Service Questionnaire Analysis

The membership service questionnaire which went out in January along with annual dues bills to all members in the U.S., except students, drew a response from 1296, or 44.1% — a high return as such questionnaires go. The replies of the membership were the basis for the SMPTE Board of Governors' action reported in the June *Journal* — chiefly that of authorizing a 20% increase in the size of the *Journal*. In response to membership demands for more tutorial and "how-to" papers, Editorial Vice-President Norwood Simmons has instructed the Papers Committee to apply greater effort in that direction.

Comments or suggestions relating to *Journal* practices are in order at any time. However, after looking through the analysis, members may well feel prompted to express their personal point of view. In this connection open letters will be welcomed by Norwood Simmons, 6706 Santa Monica Blvd., Hollywood 38, Calif.

The questions as they appeared in the questionnaire are shown below in boldface type, with tabulation by number of members and by percentage of the total of 1296 replies.

THE JOURNAL AND THE SOCIETY'S ACTIVITIES

1. Do you find the Journal satisfactory as it is?

Yes	No	Partly	No Opinion
900 (69.4%)	67 (5.2%)	115 (8.9%)	214 (16.5%)

If you think that improvements should be made, would you say that:

(a) articles are too obscure or technical?

Yes	No	Partly	No Opinion
172 (13.4%)	166 (12.8%)	85 (6.5%)	873 (67.3%)

(b) **articles should be more technical?**

Yes	No	Partly	No Opinion
78 (6.0%)	195 (15.1%)	26 (2.0%)	997 (76.9%)

(c) **the Journal would be more useful if it contained more "how to" papers about TV films, magnetic editing, etc.?**

Yes	No	Partly	No Opinion
550 (42.4%)	51 (4.0%)	15 (1.1%)	680 (52.5%)

(d) Journal issues should contain more papers?

Yes	No	Partly	No Opinion
251 (19.3%)	115 (8.9%)	13 (1.1%)	917 (70.7%)

2. What general criticism of the Journal can you offer and what suggestions would you make for improving it?

I. *GENERAL*

A. Subject Matter

A general evaluation of comments shows a marked preoccupation with the balance between the cinematographic and television fields. The membership asks for treatment of the interrelated aspects of both fields with emphasis, on the one hand, on problems and developments in production, processing and projection of motion-picture film for television applications and, on the other, on television techniques making use of cinematographic products and skills.

B. Manner of Presentation

The overwhelming demand is for descriptions and discussions that have practical application to members' own experience and work in the field. The membership asks for papers that are technical, but not purely theoretical, and written in a form acceptable to the greatest number. This means the avoidance, in so far as is possible, of detailed scientific theory, especially mathematical, and concentration on useful principles expressed in clear and simple language.

II. *SPECIFIC*

In the following listing of specific comments the order reflects in general the frequency with which the comment appears. Those most frequently occurring have been emphasized by a figure in parenthesis showing the actual number of times the comment was made.

A. The content of the Journal should:

1. be presented in a form designed to be of the greatest practical use to the majority of members, avoiding abstruse theory and emphasizing clarity and simplicity (36);
2. include more and better photographs and diagrams (26), use color where possible (5);
3. put more emphasis on techniques and developments in the television field, with particular attention to those aspects involving motion picture applications (33);
4. devote more space to new products and developments, with evaluation (24);
5. include more information on three-dimensional films (18);
6. give preference to cinematographic aspects of both motion-picture work and television (19);
7. emphasize practical production problems rather than discussions of scientific and engineering data (10); in particular, information should be given that would be helpful to the work of small production units (4);
8. have more diversified coverage (7);
9. give more attention to audio problems (7);
10. consider theater and projection problems so as to be of practical assistance to exhibitors (7);
11. include tutorial articles designed to appeal to students and non-engineers (6);
12. give more attention to discussion of aesthetic standards (4);
13. give more attention to the following: (a) color cinematography; (b) reversal films for television; (c) foreign techniques, processes and equipment; (d) film processing and laboratory developments; (e) studio lighting; (f) industrial photography; (g) film recording; (h) electronic solutions; (i) personnel problems of the industry, including union regulations, etc.; (j) techniques of individual jobs in motion-picture and television fields.

B. The content of the Journal should NOT:

1. put so much emphasis on television (18);
2. put so much emphasis on high-speed photography (13);
3. include so many articles on proprietary products written so as to give the impression of being disguised commercials (13);
4. devote so much attention to: (a) film processing; (b) magnetic recording; (c) electronics; (d) military research; (e) acoustics; (f) theater design.

C. The Journal should:

1. publish advertisements (11);
2. present series of articles to cover whole scope of a specific subject from first principles to latest developments (7);
3. include nontechnical summaries in difficult articles; publish better summaries in general (6);
4. provide a glossary of technical terms;
5. in the first part of each article introduce the

subject and summarize the conclusions in non-technical terms;

6. give an annual or semiannual review of important developments in all fields in language understandable to the layman;

7. include reviews and abstracts of foreign publications;

8. publish more book reviews;

9. publish tutorial, "how to" articles separately in special editions or sections;

10. include a question and answer section, with bibliographies;

11. include a section for correspondence, "tips," "time-savers," etc.;

12. give more space to advertising situations available and wanted;

13. publish more discussions at end of papers where possible;

14. make available more special issues with collections of papers on related subjects;

15. publish convention papers separately from the regular *Journal* material (which should therefore be increased);

16. give abstracts of all papers presented at conventions;

17. make available catalogs of motion-picture, television and still-photography equipment;

18. include a section on news of the industry;

19. give more space to letters to the editor;

20. abstract important articles in other publications;

21. abstract highlights of important addresses before all sections of the Society (in editorial section);

22. give space to news of membership and activities;

23. reprint major standards periodically;

24. include editorials;

25. present subject matter arranged in categories;

26. republish earlier important papers;

27. give more information on how members can contribute to committee work and other Society activities;

28. publish photographs and biographies of authors with their articles.

D. General Statements

1. *Journal* should appear on time and reach members during month of publication (21).

2. Convention papers should appear sooner after presentation (6).

3. Timelier advance notice of meetings should be given.

4. Tape recordings of discussions at conventions as well as of papers should be made available.

5. Officer nominations should be more evenly distributed by geographical areas.

6. Format changes might include: (a) size increase to $8^1/_2$ by 11; (b) larger type; (c) rigid cover; (d) better index; (e) bi-monthly publication; (f) loose-leaf reprint service.

7. Send forms soliciting articles to all members.

3. Mark your 1st and 2nd choices for future subject emphasis in the Journal, or make suggestions:

Subject	*1st Choice*	*2nd Choice*	*Suggested*	*Total*
Acoustics	22	26	102	150
Animation	26	18	74	118
Cinematography	92	47	150	289
Color	110	64	155	329
Editing	21	32	89	142
Education	8	19	48	75
Films	11	17	67	95
High-Speed Photog.	61	29	69	159
Lighting	23	52	130	205
New Products	47	53	158	258
Optics	39	64	134	237
Processing	38	48	121	207
Production	28	43	91	162
Projection	35	20	102	157
16mm	80	58	153	291
Sound Recording	109	67	165	341
Sound Reproduction	46	68	130	244
Studios	7	19	74	100
Television	131	85	169	385
Theater	13	11	62	86
Theater Television	27	39	108	174
Stereoscopy (written in)	18	9	32	59

First, it should be noted that the "overlooked" subject of Stereoscopy drew a heavy write-in.

Second, except for "Theater Television," the subject of television was not subdivided, but other portions of the Society's field are generally divided and subdivided — sound, for instance, into recording and reproduction.

A recapitulation of subjects in order of number of total choices is:

1. Television	385	11. Theater TV	174
2. Sound Recording	341	12. Production	162
3. Color	329	13. High-Speed Photog.	159
4. 16mm	291	14. Projection	157
5. Cinematography	289	15. Acoustics	150
6. New Products	258	16. Editing	142
7. Sound Reprod.	244	17. Animation	118
8. Optics	237	18. Films	95
9. Processing	207	19. Theater	86
10. Lighting	205	20. Education	75
		21. Stereoscopy	59

CONVENTIONS

4. Do you regularly attend conventions?

Yes	Occasionally	No	No Opinion
146 (11.3%)	68 (5.2%)	177 (13.6%)	98 (7.6%)

Or only when they are held near you?

807 (62.3%)

5. Do you think members would be better served if the customary Spring Convention were replaced by several regional meetings of two-day duration?

Yes	No	Both	No Opinion
539 (41.6%)	366 (28.2%)	6 (0.5%)	385 (29.7%)

If in favor of two-day meetings, list choices of cities:

City	*1st Choice*	*Only Choice*	*Total*
New York	129	60	189
Los Angeles	71	55	126
Chicago	51	27	78
Washington, D. C.	16	..	16
San Francisco	8	3	11
Rochester	9	2	11

Cities receiving a total of 6 to 10 checks were: Atlanta, Boston, Cleveland, Dallas, Detroit and Philadelphia.

Cities receiving a total of 1 to 5 checks were: Albuquerque, Austin, Cincinnati, Denver, El Paso, Fort Worth, Houston, Jacksonville, Kansas City, Lansing, Milwaukee, Nashville, New Haven, Phoenix, Pittsburgh, St. Louis, Salt Lake City, San Antonio and Seattle.

MAGAZINES

Members were asked to check a list of magazines. The tabulation will not be published because the Society cannot supply comparative statistics about trade magazines. It may be said, however, that the results were consistent with subject choices indicated in Item 3 above.

In comparison with the subject coverage of the magazines you have checked, does the SMPTE Journal:

duplicate	11	(0.8%)
(partially duplicate)	10	(0.8%)
adequately supplement	849	(65.5%)
inadequately supplement	95	(7.3%)
(no opinion)	331	(25.6%)
Total	1296	(100%)

PROFESSIONAL SOCIETIES

Single check those of the following to which you belong. Make a second check at those with which a conflict of convention dates would be most serious:

Society	*Two Checks*	*One Check*	*Total*
Acoustical Society of America	14	38	52
American Chemical Society	8	53	61
American Institute of Electrical Engineers	8	59	67
American Physical Society	2	40	42
Audio Engineering Society	11	58	69
Biological Photographic Association	8	20	28
Illuminating Engineering Society	1	14	15
Institute of Radio Engineers	68	189	257
Instrument Society of America	4	18	22
National Electronics Conference	7	29	36
Optical Society of America	17	55	72
Photographic Society of America	20	125	145
Society of Photographic Engineers	22	63	85

There were 38 societies' names written in. Of these, only two attained as much as a total of 10 write-ins each. They were the American Association for the Advancement of Science and the American Society of Photogrammetry.—*D.C.*

Status of Motion-Picture Standards

Standards, withdrawals and proposals are shown below according to their status as of February 1953. The six-month index, published as Part II of the June 1953 *Journal* (p. 761), brings the list as published below up to date.

A "New Index to American Standards and Recommendations," of eight full pages, is available at no charge to all who request it from Society Headquarters, regardless of whether it is to go into a binder. Copies should be obtained to replace earlier indexes in all SMPTE binders of standards.

If you have an SMPTE (3-post) binder and would like to receive advance notice of all future new and revised standards, please advise Society Headquarters.

The complete assembly of heavy binder and the 75 current standards is now available at $15.00 (plus 3% sales tax on deliveries within New York City; or plus $0.50 extra for postage on foreign orders).

Subject		*Vol., page, issue*
Apertures, Camera		
8mm	**Z22.19–1950**	**54:** 501, Apr. 1950
16mm	**Z22.7 –1950**	**54:** 495, Apr. 1950
35mm	**Z22.59–1947***	**50:** 287, Mar. 1948
Apertures, Printer		
16mm Contact (positive from negative)	**Z22.48–1946**	**46:** 300, Apr. 1946
16mm Contact (reversal dupes)	**Z22.49–1946**	**46:** 301, Apr. 1946
35mm to 16mm (16mm positive prints)	**Z22.46–1946**	**46:** 298, Apr. 1946
35mm to 16mm (16mm dupe negative)	**Z22.47–1946**	**46:** 299, Apr. 1946
16mm to 35mm Enlargement Ratio	**PH22.92–1953**	**60:** 72, Jan. 1953
Apertures, Projector		
8mm	**Z22.20–1950**	**54:** 503, Apr. 1950
16mm	**Z22.8 –1950**	**45:** 498, Apr. 1950
35mm Sound	**Z22.58–1947***	**50:** 286, Mar. 1948
Cores for Raw Stock Film		
16mm	**PH22.38–1952**	**59:** 429, Nov. 1952
35mm	**Z22.37–1944**	**47:** 262, Sept. 1946
Density Measurements of Film (includes Z38.2.5–1946)	**Z22.27–1947**	**50:** 283, Mar. 1948
Edge Numbering, 16mm Film	**PH22.83–1952**	**59:** 428, Nov. 1952
Film Dimensions		
8mm	**Z22.17–1947***	**49:** 176, Aug. 1947
16mm Silent	**Z22.5 –1947***	**59:** 529, Dec. 1952
16mm Sound	**Z22.12–1947***	**59:** 531, Dec. 1952
32mm Negative and Positive, Sound	**Z22.71–1950**	**56:** 237, Feb. 1951
32mm Negative and Positive, Silent	**Z22.72–1950**	**56:** 239, Feb. 1951
32mm on 35mm Negative	**PH22.73–1951**	**56:** 685, June 1951
35mm Negative	**Z22.34–1949**	**52:** 358, Mar. 1949
35mm Positive	**Z22.36–1947***	**49:** 179, Aug. 1947
35mm Alternate Positive-Negative	**PH22.1 –1953**	**60:** 67, Jan. 1953

* The asterisk denotes that the standard was in process of revision, as of February 1953.

Subject		*Vol., page, issue*
Film Usage, Camera		
8mm	**Z22.21–1946***	**46:** 291, Apr. 1946
16mm Double Perforated	**Z22.9 –1946***	**46:** 289, Apr. 1946
16mm Single Perforated	**Z22.15–1946***	**57:** 581, Dec. 1951
35mm	**Z22.2 –1946***	**46:** 287, Apr. 1946
Film Usage, Projector		
8mm	**Z22.22–1947***	**49:** 557, Dec. 1947
16mm Double Perforated	**Z22.10–1947***	**49:** 555, Dec. 1947
16mm Single Perforated	**Z22.16–1947***	**57:** 582, Dec. 1951
35mm	**Z22.3 –1946***	**46:** 288, Apr. 1946
Focus Scales, 16mm and 8mm Cameras	**PH22.74–1951**	**56:** 687, June 1951
Lamps, 16mm and 8mm Projectors		
Base-Up Type	**PH22.84–1953**	**60:** 69, Jan. 1953
Base-Down Type	**PH22.85–1953**	**60:** 71, Jan. 1953
Lens Mounting, 16mm and 8mm Cameras	**PH22.76–1951**	**56:** 688, June 1951
Nomenclature, Film	**Z22.56–1947***	**50:** 275, Mar. 1948
Projection Rooms and Lenses	**Z22.28–1946***	**47:** 259, Sept. 1946
Reels		
8mm	**Z22.23–1941***	**36:** 241, Mar. 1941
16mm (corrected)	**PH22.11–1952***	**58:** 535, June 1952
35mm	**Z22.4 –1941***	**36:** 222, Mar. 1941
Reel Spindles, 16mm	**PH22.50–1952**	**59:** 525, Dec. 1952
Release Prints, 35mm	**Z22.55–1947***	**50:** 284, Mar. 1948
Safety Film	**Z22.31–1946***	**47:** 261, Sept. 1946
Screen		
Brightness	**Z22.39–1944***	**58:** 452, May 1952
Dimensions	**Z22.29–1948**	**51:** 535, Nov. 1948
Mounting Frames	**Z22.78–1950**	**54:** 505, Apr. 1950
Sound Transmission	**PH22.82–1951**	**57:** 171, Aug. 1951
Sound-Track Dimensions		
16mm	**Z22.41–1946***	**46:** 293, Apr. 1946
35mm	**Z22.40–1950**	**56:** 114, Jan. 1951
35mm Double Width Push-Pull, Normal	**Z22.69–1948**	**51:** 547, Nov. 1948
35mm Double Width Push-Pull, Offset	**Z22.70–1948**	**51:** 548, Nov. 1948
Splices		
8mm	**PH22.77–1952**	**58:** 541, June 1952
16mm	**PH22.24–1952**	**58:** 539, June 1952
Sprockets		
16mm	**(SMPTE Recommended Practice)**	
35mm	**Z22.35–1947***	**49:** 178, Aug. 1947
Test Films		
16mm 400-Cycle Signal Level	**Z22.45–1946***	**46:** 297, Apr. 1946
3000-Cycle Flutter	**Z22.43–1946**	**46:** 295, Apr. 1946
5000-Cycle Sound Focusing		
7000-Cycle Sound Focusing	**Z22.42–1946***	**46:** 294, Apr. 1946

Subject		*Vol., page, issue*
Buzz-Track	**Z22.57–1947***	**51:** 537, Nov. 1948
Multi-Frequency	**Z22.44–1946**	**46:** 296, Apr. 1946
Travel Ghost	**Z22.54–1946***	**46:** 309, Apr. 1946
Sound Projector	**Z22.79–1950**	**54:** 507, Apr. 1950
Scanning Beam, Laboratory Type (corrected)	**PH22.80–1950**	**59:** 430, Nov. 1952
Scanning Beam, Service Type (corrected)	**PH22.81–1950**	**59:** 430, Nov. 1952
35mm 1000-Cycle Balancing	**Z22.67–1948**	**51:** 545, Nov. 1948
7000-Cycle Sound Focusing	**Z22.61–1949**	**54:** 107, Jan. 1950
9000-Cycle Sound Focusing	**Z22.62–1948**	**51:** 541, Nov. 1948
Buzz-Track	**Z22.68–1949**	**54:** 108, Jan. 1950
Scanning Beam, Laboratory Type	**Z22.66–1948**	**51:** 543, Nov. 1948
Scanning Beam, Service Type	**Z22.65–1948**	**51:** 542, Nov. 1948
Theater Test Reel	**Z22.60–1948**	**51:** 539, Nov. 1948
Test Methods, 16mm Sound Distortion		
Cross Modulation, Variable-Area	**Z22.52–1946**	**46:** 305, Apr. 1946
Intermodulation, Variable-Density	**Z22.51–1946**	**46:** 303, Apr. 1946
Test Plate		
Resolution Target, 16mm Projector	**Z22.53–1946***	**46:** 307, Apr. 1946

Standards Withdrawn

No.	*Title*	*Vol., page, issue*
Z22.6 –1941	Projector Sprockets for 16mm Film	**36:** 224, Mar. 1941
Z22.13–1941	For current standard see Z22.7–1950 Camera Aperture for 16mm Sound Film	**36:** 231, Mar. 1941
Z22.14–1941	For current standard see Z22.8–1950 Projector Aperture for 16mm Sound Film	**36:** 232, Mar. 1941
Z22.18–1941	8-Tooth Projector Sprockets for 8mm Motion Picture Film	**36:** 236, Mar. 1941
Z22.25–1941	American Recommended Practice for Film Splices Negative and Positive for 16mm Sound Film (See PH22.24)	**36:** 243, Mar. 1941
Z22.26–1941	American Recommended Practice for Sensitometry	**36:** 244, Mar. 1941
Z22.30–1941	American Recommended Practice for Nomenclature	**36:** 248, Mar. 1941
Z22.32–1941	Cancelled	**50:** 276, Mar. 1948
	American Recommended Practice for Motion Picture Film, Theater Sound Fader Setting Instructions	**48:** 390, Apr. 1947
	American Recommended Practice for Fader Setting Instructions	**36:** 250, Mar. 1941
Z22.33–1941	(Notice of Withdrawal) American Recommended Practice for Nomenclature for Filters	**59:** 252, Mar. 1941
Z22.63	Proposed, Service-Type Multifrequency Test Film for 35mm Motion Picture Sound Reproducers	**50:** 275, Mar. 1948
Z22.64	Laboratory-Type Multifrequency Test Film for 35mm Motion Picture Sound Reproducers	**50:** 275, Mar. 1948

Proposed Standards

PH22.75	Proposed, A and B Windings of 16mm Single-Perforated Film (Third Draft)	**60:** 189, Feb. 1953
PH22.86	Proposed, Dimensions for Magnetic Sound Tracks on 35mm and 17$^1/_2$mm Motion Picture Film	**57:** 72, July 1951

No.	Title	Vol., page, issue
PH22.87	Proposed, Dimensions for Magnetic Sound Track on 16mm Motion Picture Film	**57:** 73, July 1951
PH22.88	Proposed, Dimensions for Magnetic Sound Track on 8mm Motion Picture Film	**57:** 74, July 1951
PH22.89	Proposed, Printer Light Change Cueing for 16mm Motion Picture Negative (not at Journal publication stage; available as mimeographed proposal)	
PH22.90	Proposed, Aperture Calibration of Motion Picture Lenses	**59:** 338, Oct. 1952
PH22.91	Proposed, 16mm Motion Picture Projector for Use with Monochrome Television Film Chains Operating on Full-Storage Basis (Fourth Draft)	**59:** 144, Aug. 1952
PH22.93	Proposed, 35mm Motion Picture Short Pitch Negative Film	**59:** 533, Dec. 1952
PH22.94	Proposed, Slides and Opaques for Television Film Chains (published April 1953)	

Photographic Apparatus and Processing Standards

Below are listed the numbers and titles of recently approved American Standards in the field of still photography. Additional listings of such standards will be published in the *Journal* from time to time, as they are made available, as a service to those readers who maintain an active interest in still, as well as motion-picture, photography.—*Henry Kogel*, Staff Engineer.

Photographic Apparatus, PH3

Back Window Location for Roll Film Cameras, PH3.1-1952 (Revision of Z38.4.9-1944)

Method for Determining Performance Characteristics of Focal-Plane Shutters Used in Still Picture Cameras, PH3.2-1952 (Replaces American War Standard Z52.65-1946)

Exposure-Time Markings for Focal-Plane Shutters Used in Still Picture Cameras, PH3.3-1952 (Replaces Proposed American War Standard Z52.64)

Method for Determining Performance Characteristics of Between-the-Lens Shutters Used in Still Picture Cameras, PH3.4-1952 (Replaces American War Standard Z52.63-1946)

Exposure-Time Markings for Between-the-Lens Shutters Used in Still Picture Cameras, PH3.5-1952 (Replaces American War Standard Z52.62-1946)

Tripod Connections for American Cameras, $\frac{1}{4}$-Inch-20 Thread, PH3.6-1952 (Revision of Z38.4.1-1942)

Tripod Connections for Heavy-Duty or European Cameras, $\frac{3}{8}$-Inch-16 Thread, with Adapter for $\frac{1}{4}$-Inch-20 Tripod Screws (Revision of Z38.4.2-1942), PH3.7-1952

Photographic Processing, PH4

Specifications for Sheet Film Processing Tanks, PH4.2-1952 (Revision of Z38.8.15-1949)

Specifications for Photographic Trays, PH4.3-1952

Specifications for Channel-Type Photographic Hangers, Plates and Sheet Film, PH4.4-1952

Specification for Photographic Grade Sodium Acid Sulfate, Fused, ($NaHSO_4$), (Sodium Bisulfate, Fused; Niter Cake), PH4.105-1952

Specification for Photographic Grade Sodium Sulfite, (Na_2SO_3), PH4.275-1952 (Revision of Z38.8.275-1948)

New Test Films

A folder of addenda to the Society's Test Film Catalog is now available at no charge from the Society's headquarters. Details of five new 35mm test films are listed, designed for 3-D and 2-D projector alignment, magnetic 3-track balancing, magnetic 3-track azimuth alignment, magnetic 3-track flutter test and magnetic 3-track multifrequency test. There is also a 16mm magnetic azimuth alignment test film. These films have been approved by technical committees of the Society and of the Motion Picture Research Council.

Theater Television

Only by its appeal will theater television survive, for FCC Docket 9552 is now closed by a finding of June 24, Commissioner Hennock dissenting. The Commission speaks:

". . . theatre television should operate as a common carrier on frequencies presently allocated for such services, we of course expect that there will be cooperation among common carriers in resolving frequency conflicts. . . . There has been no persuasive evidence in this proceeding to the effect that the existing common carrier allocations are not adequate. . . . In any event, we do not feel this is the proper proceeding to reevaluate the sufficiency of present allocations to the common carrier service. . . . If the proponents of theatre television feel that existing common carriers cannot supply them with the service they desire, they are free to take the necessary steps to establish a separate carrier . . . or to require existing carriers to render a reasonable service. . . . We recognize [theater television in general] as an existing service which will continue to expand or not depending upon public acceptance and support thereof. . . . Our concern is merely with the question of whether there should be a separate allocation of frequencies for the exclusive use of this service. Finding that there is no necessity for such an allocation, we have decided that this proceeding should now be terminated." *Note:* Commissioner Hennock believes the hearing incomplete, the finding unwarranted since "public interest" was not specifically determined and, in opposing, draws critical inference that ". . . this question will be decided when a specific application for service is filed."—*B.N.*

Book Reviews

The Television Manual

By William Hodapp. Published (1953) by Farrar, Straus and Young, 101 Fifth Ave., New York 3, N.Y. i–xiv, 289 pp. text + $5\frac{1}{2}$ pp. index. $5\frac{1}{2} \times 8\frac{1}{8}$ in. Not illustrated.

This book, as stated by the publishers, is a "guide to TV production and programming for education, public affairs and entertainment." It is a very good book from this point of view, and is no doubt directed toward that group of workers in television broadcasting who are intimately concerned with the business of building and producing programs to satisfy the insatiable appetite of this demanding new entertainment medium. As a program guide, it fills a real need in the field of television broadcasting.

Although not a technical book in any sense, it will prove of interest to those engineering and technical workers in the field who might feel the need of an authoritative work on television production and programming techniques, and for this purpose it should prove a valuable addition to the television engineer's reference library. Because of the author's practical experience with NBC, the information contained in this volume can be considered authoritative as well as practical.

The author discusses program formats and sources, production and operations, studio and remote settings, staging, films for television, educational TV operation, the personnel engaged in producing a complete television program on the air and their various duties and responsibilities. There is an interesting discussion of television today and tomorrow.

A well-prepared appendix provides some very excellent information for new people entering the field of television programming as well as station management. For new television station managers this volume will be a helpful place to find practical information concerning important phases of station operation, typical network costs, standard business contract forms, a glossary of TV production terms, recommended sources of information for further study, etc.

The book would have been vastly improved through the addition of some carefully selected illustrations, and it is hoped that in his second edition the author will make up for this deficiency.—*Scott Helt*, Allen B. Du Mont Laboratories, Inc., 750 Bloomfield Ave., Clifton, N.J.

Designing for TV,

The Arts and Crafts in Television

By Robert J. Wade. Published (1953) by Pellegrini and Cudahy, 101 Fifth Ave., New York 3, N.Y. 203 pp. + 12 pp. index. Numerous illus. 8 × 11½ in. $8.50.

The time is ripe for specialized and definitive books on the various aspects of the new television medium. Television engineering has long since passed from experimentation into practical day-to-day operation, and television production too has borrowed what it must from the techniques of stagecraft, from motion pictures, from display advertising and a dozen other fields, passed through the experimental period and is settling down into a fairly well standardized television technique.

Designing for TV is a book for the set designer, the graphic artist, and naturally for the director as well, since the very intensity of production in this medium demands that everyone have a pretty clear idea of the other man's problems. It will be particularly valuable for the TV station production manager, who must decide on the type of scenery to be built, the space necessary for construction and painting, and must devise short-cut techniques ("nickel-tricks" as Chuck Holden calls them at ABC) to get "almost the same effect" at negligible time and cost. Wade's book is frankly a glamour-book, lavishly supplied with illustrations, many of which seem to occupy a lot of space without conveying too much actual information. Yet the solid stuff is there — and the glamour factor should add greatly to the inspirational value of the book when it falls into the hands of students of the medium.

Although described by the author as a reference book, *Designing for TV* is written in such a personable style that one frequently looks up a subject and finds himself beguiled into reading well beyond his topic. It conveys a feeling of immediate contact with the medium, of getting "the straight stuff right from the horse's mouth" which is invaluable in a book of this kind. Wade is candid in his accuracy: "distemper colors," he reports, "include a palette of hot unpleasant browns, screeching yellows, an assortment of half-caste putty gamboges and pinks . . . a rather beautiful turquoise [etc.]." He is honest in his opinions. In discussing the cameo technique, a method of producing dramatic shows largely in close shots with a black background, he has this to say: "While graphic artists for obvious reasons do not cotton to this technical development, the method has many excellent features and provides means of presenting certain types of dramatic fare in an atmosphere of intimacy. The viewer, not always without some embarrassment, is enabled to watch and to eavesdrop at close range during emotional scenes and can observe, if he has the clinical interest, enlargements of varied eyes, ears, noses and throats reacting to different stimuli."

Although priced nearly in the luxury class, this book should have wide usefulness. It belongs in every television library and close at hand on every production man's desk.—*Rudy Bretz*, Television Consultant, Park Trail, Croton-on-Hudson, N.Y.

Home Music Systems:

How to Build and Enjoy Them

By Edward Tatnall Canby. Published (1953) by Harper & Brothers, 49 E. 33d St., New York 16, N.Y., i–x, 296 pp. text + 4 pp. index. Illus. $5\frac{1}{2} \times 8$ in. Price $3.95.

Mr. Canby, who regularly reviews records in *Audio Engineering*, is clearly aiming his book at the considerable audience that follows his reviews and also at the ever-growing number of good-sound enthusiasts interested in choosing and installing their own sound equipment. Primarily intended for the amateur intent on getting the utmost out of his commercial LP records, the book has a store of clearly expressed information on the theory and performance of each component of a sound system — turntables, pickup heads, preamplifiers, amplifiers and speakers — as well as on the various refining gadgets now available to go with them. There is good practical guidance on quality and price of equipment offered on the market, and much helpful advice is given on speaker enclosures and other aspects of home installation. This should be a handy reference book even for the sound engineer, who is all too likely these days to be in frequent demand for informal help with living-room music systems.—*D.C.*

Scientific Film Review

This is a new quarterly of criticism being issued by the Scientific Film Association in London, as a supplement to the *Monthly Film Bulletin* of the British Film Institute. It is distributed to all members of those two organizations and may be obtained by others from the General Secretary, Scientific Film Association, 164 Shaftesbury Ave., London W.C.2. The first issue contained full details on 17 new films, ranging from purely scientific instructional films on electricity to films on engineering, textiles and medicine.

Current Literature

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

vol. 34, Apr. 1953

An Animation Stand for TV Film Production (p. 162) *W. R. Witherell, Jr.*

The Magnasync Recorder (p. 165) *D. J. White*

The New Ansco Color Film and Process (p. 166) *R. A. Mitchell*

vol. 34, May 1953

2-D, 3-D, Wide-Screen, or All Three (p. 210) *A. Gavin*

Columbia Studio's 3-D Camera (p. 215)

Filming the Big Dimension (p. 216) *L. Shamroy*

Terror in 3-Dimension (p. 218) *H. A. Lightman*

vol. 34, June 1953

Some Basic Principles of 3-D Cinematography (p. 266) *F. A. Ramsdell*

One Camera, One Film for 3-D (p. 269)

A New Camera Dolly for Films and Television (p. 273) *K. Freund*

The Hallen Magnetic Film Recorder (p. 274) *H. Powell*

Audio Engineering

vol. 37, May 1953

Handbook of Sound Reproduction, Chapter 11: Loudspeaker Mounting (p. 34) *E. M. Villchur*

vol. 37, no. 7, July 1953

Handbook of Sound Reproduction, Chapter 12: The Power Amplifier, Pt. 1 (p. 26) *E. M. Villchur*

Bild und Ton

vol. 6, Mar. 1953

Umfeldbeleuchtung bei der Kinoprojektion (p. 67) *R. Reuther*

Entwicklungsstand der Bildprojektoren und Bildtonanlagen für 16-mm-Film (p. 80) G. Pierschel

British Kinematography

vol. 22, Mar. 1953

Aerial Filming for "The Sound Barrier" (p. 68) *A. Squire*

Pinewood Studios. A Review of Recent Technical Developments (p. 76) *R. L. Hoult*
The Film Studio. The Development of Equipment and Operation (p. 78) *B. Honri*

vol. 22, Apr. 1953

The Quality of Television and Kinematograph Pictures (p. 104) *L. C. Jesty*
Observations on Cine-Stereoscopy (p. 100)

vol. 22, May 1953

Modern Tendencies in 16mm Projector Design (p. 140) *C. B. Watkinson*
Eastman Colour Films for Professional Motion Picture Work (p. 146) *G. J. Craig*

vol. 22, June 1953

The Flammability and Flash Point of Cellulose Acetate Film Containing Various Amounts of Cellulose Nitrate (p. 172) *R. W. Pickard and D. Hird*
Production Techniques in the Making of Educational Films (p. 176) *F. A. Hoare*

International Photographer

vol. 25, Apr. 1953

From "Talkers" to 3-D (p. 5) *T. Krasner, V. Heutschy and R. Ross*
Prismatic Color Corrector (p. 12)

vol. 25, June 1953

Processing Color Film (p. 22) *G. Ashton and P. Jenkins*

International Projectionist

vol. 28, Apr. 1953

CinemaScope: What it is, How it Works (p. 7) *A. Gavin*
Types of Theatre Sound Reproducers. Pt. IV, The Sound-head (p. 11) *R. A. Mitchell*
World-Premiere of Altec-Paramount 4-Projector, No Intermission, 3-D Color Showing (p. 15)

vol. 28, May 1953

Visibility Factors in Projection. Pt. 1, Panorama vs. Stereoscopy (p. 7) *R. A. Mitchell*
Projected Light and the Curved Screen (p. 12)
The "New" Cooling Systems (p. 13) *C. A. Hahn*
Addendum: 3-D Projection: Motion Picture Research Council (p. 14)
Motiograph's Stereo Sound (p. 14)

vol. 28, June 1953

Wide Screen Single-Film 3-D Predicted (p. 7) *J. A. Norling*
Visibility Factors in Projection. Pt. 2, Light Problems of 3-D and Panorama (p. 11) *R. A. Mitchell*
The "Hypergonar" Lens Process (p. 14) *H. Chretien*

Journal of the Audio Engineering Society

vol. 1, no. 2, Apr. 1953

History and Development of Stereophonic Sound Recording (p. 176) *R. H. Snyder*

Kino-Technik

vol. 7, May 1953

Der Raumfilm in der Debatte: Internationale Umschau der 3-D-Filmtechnik (p. 126) *L. Busch*
Plastischer Film im Blickfeld der Patentschriften (p. 129) *H. Atorf*
Das Raumbildton-Verfahren System Klangfilm "Stereodyn" (p. 132) *H. Friess*
Stereoskopie muss durch Stereophonie ergänzt werden (p. 134) *M. Ulner*
Das Stereofilm-Verfahren System Zeiss Ikon (p. 136) *O. Vierling*

vol. 7, no. 6, June 1953

Untersuchungen und Erfahrungen mit Sicherheitsfilm (p. 156) *A. Narath*
Sicherheits- und Nitrofilmnach Brennbarkeit verglichen (p. 158)
Plastischer Film im Blickfeld der Patentschriften (p. 162) *H. Atorf*
Technische Hinweise zur Stereo-Filmvorführung (p. 164) *H. Tümmel*

Motion Picture Herald

vols. 190 and 191 — Mar. 14, 1953 (p. 30); Apr. 4 (p. 28); Apr. 25 (p. 24); May 9 (p. 23); June 13 (p. 19).
A series of installments on "The Story of 3-D from 1613 to 1953" by *Martin Quigley, Jr.* The previous sections of this article were published in the issues of Feb. 7 (p. 16) and Feb. 21 (p. 14)

vol. 192, July 4, 1953

Single Film 3-D Claimed by Norling (p. 23)

Motion Picture Herald (Better Theatres Sec.)

vol. 192, July 4, 1953

Crisis in Sound, 1953 (p. 11)
Precision Requirements of 3-D: Shutter Synchronization, Interlocking and Alignment (p. 15) *G. Gagliardi*

Philips Technical Review

vol. 14, Apr. 1953

A Steel Picture-Tube for Television Reception (p. 281) *J. de Gier, T. Hagenberg, H. J. Meerkamp van Embden, J. A. M. Smelt and O. L. van Steenis*

Radio & Television News

vol. 50, July 1953

The Dage Industrial TV Camera (p. 31) *H. E. Ennes*

Tele-Tech

vol. 12, July 1953

Color Television—Its Status Today and a Look into the Future (p. 54) *W. R. G. Baker*
Multicon—A New TV Camera Tube (p. 57) *H. Smith*

Obituaries

Herbert Griffin died on May 6, 1953, at Santa Monica, Calif. He was Vice-President and a Director of International Projector Corp.

Born in London in 1887, he was educated there and in the U.S. and was subsequently associated with several engineering firms. In 1915 he joined Nicholas Power Co., makers of projectors, and, except for an excursion as director of motion-picture activities for the YMCA with the AEF from 1916 to 1919, he stayed with Nicholas Power until the firm merged with International Projector Corp., makers of Simplex projectors. He became Vice-President and a Director of that firm in 1936.

Herbert Griffin will be especially remembered by the Society's members as one active in its affairs for many years. He was President in 1943–44 and a Fellow.

Leopold E. Greiner, Jr., President of Greiner Glass Industries Company of New York, died in May 1953. Mr. Greiner had pioneered in the precision etching of various glass devices for use in motion-picture equipment. He was responsible for the design and production of the widely used 16mm Projector Lens Resolution Target which is based on American Standard Z22.53.

Riborg Graf Mann died at his home in East Hampton, N.Y. on June 13, 1953. He was 52 years old.

After graduation from the Massachusetts Institute of Technology, where he was a member of the Student Army Training Corps of World War I, he entered the radio and motion-picture field. In 1927 he joined the Lee DeForest Laboratories where he performed experimental work on motion-picture sound equipment. In 1928 he traveled extensively for Movietone News, both in this country and abroad, pioneering in the making of sound newsreels. He then transferred to Trans-Lux where he helped build their first Newsreel Theater in New York. For the past 20 years he had been Chief Engineer of Pathe News.

During World War II, Mr. Mann was given a leave of absence from Pathe and served for 36 months in the United States Coast Guard Reserve. He attained the rank of Lieutenant-Commander, commanding a Destroyer Escort both in the Atlantic and Pacific areas.

He had been a member of the Society of Motion Picture and Television Engineers since 1934.

SMPTE Lapel Pins

The Society has available for mailing its gold and blue enamel lapel pin, with a screw back. The pin is a ½-in. reproduction of the Society symbol — the film, sprocket and television tube — which appears on the *Journal* cover. The price of the pin is $4.00, including Federal Tax; in New York City, add 3% sales tax.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 Membership Directory.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Adams, Robert A., Sound Engineer, Consolidated Amusement Co., Honolulu, Hawaii. (A)

Alder, Sidney M., Sales Engineer, Minnesota Mining & Mfg. Co., 6411 Randolph St., Los Angeles, Calif. (A)

Alexander, John, University of Southern California. **Mail:** 3049 Royal St., Los Angeles 7, Calif. (S)

Alexander, Richard G., Film Technician, Filmservice Laboratory. **Mail:** 11720 Magnolia Blvd., North Hollywood, Calif. (M)

Alf, Herbert A., Motion-Picture Producer. **Mail:** 6245 Scenic Ave., Los Angeles 28, Calif. (A)

Allen, J. Longworth, University of Southern California. **Mail:** 643 W. 30 St., Los Angeles 7, Calif. (S)

Andersen, Helmer W., Television Recording, Columbia Broadcasting System. **Mail:** 2337 Lake View Ave., Los Angeles 39, Calif. (A)

Applegate, Vernon C., Fishery Research Biologist, United States Fish and Wildlife Service, P.O. Box 28, Rogers City, Mich. (A)

Arndt, Jack E., Motion-Picture Sound Service, Altec Service Corp. **Mail:** 925 Buckingham St., S.W., Grand Rapids, Mich. (A)

Arnold, Leroy H. J., University of Southern California. **Mail:** 1615 Crenshaw Blvd., Torrance, Calif. (S)

Arriola, William A., Photographer and Motion-Picture Technician, Alexander Film Co. **Mail:** 214½ East Dale, Colorado Springs, Colo. (M)

Babet, Philip, University of California at Los Angeles. **Mail:** 904½ Tiverton Ave., Los Angeles 24, Calif. (S)

Bachrach, Ernest A., Portrait Photographer, RKO Studio. **Mail:** 5612 Canyonside Rd., La Crescenta, Calif. (A)

Balousek, Ray, Photographer, 24 Custer St., Detroit, Mich. (A)

Barden, Ron, University of Southern California. **Mail:** 1138 W. 28 St., Los Angeles 7, Calif. (S)

Baribault, Phillip, Sound-Cameraman, 124 North Lincoln St., Burbank, Calif. (A)

Beemer, Richard N., Motion-Picture Writer, Director, North American Aviation, Inc. **Mail:** 4547½ Carson St., Long Beach 8, Calif. (A)

Beiswenger, Bruce R., Assistant Film Director, Television Station WHAM-TV. **Mail:** 96 Fernwood Park, Rochester 9, N.Y. (M)

Benson, Rupert M., Jr., University of Southern California. **Mail:** 4959 Cahuenga Blvd., North Hollywood, Calif. (S)

Beyoghlian, Agop, University of Southern California. **Mail:** 1533 Fourth Ave., Los Angeles 19, Calif. (S)

Bolm, Olaf A., TV Commercials (Film), Young & Rubicam, Inc. **Mail:** 2061 North Sycamore Ave., Hollywood 28, Calif. (A)

Bomke, Robert A., University of Southern California. **Mail:** 14834 Lakewood Blvd., Paramount, Calif. (S)

Borschell, E. J., Sound Engineer, Wayne Fellows, Prods., Inc., 1022 Palm Ave., Hollywood 46, Calif. (A)

Bowder, James I., Cinemaphotographer, Hughes Aircraft Co. **Mail:** 7422 South Harvard Blvd., Los Angeles 47, Calif. (A)

Bowen, David, Cinematographer, Hughes Aircraft Co. **Mail:** 5613½ North Huntington Dr., Los Angeles, Calif. (A)

Bullock, Edward A., Engineer, Technical Service, Inc., 30865 W. Five Mile Rd., Livonia Mich. (M)

Burson, H. E., Jr., Motion-Picture Specialist, Hughes Aircraft Co. **Mail:** 3347 Canfield Ave., Los Angeles 34, Calif. (A)

Calderon, Ruben A., Owner, Azteca Films, Inc., 1743 South Vermont Ave., Los Angeles, Calif. (A)

Carlisle, Kenneth S., Projectionist, Fox Inter-Mountain Amusements. **Mail:** 936 Gladstone, Sheridan, Wyo. (A)

Cartwright, William Tilton, University of Southern California. **Mail:** 6232 La Mirada, Apt. 2, Los Angeles, Calif. (S)

Chatterjee, Sushilkumar, University of Southern California. **Mail:** 4240½ Third Ave., Los Angeles 8, Calif. (S)

Chylousky, Edward, University of Southern California. **Mail:** 2260 Cranston Rd., University Heights 18, Ohio. (S)

Cohen, Robert C., Production Designer. **Mail:** 177 South Sycamore Ave., Los Angeles 36, Calif. (A)

Conway, Robert E., Projectionist, Fox West Coast Theatres. **Mail:** 1715—30 St., San Diego 2, Calif. (A)

Cookley, Stephen, University of Southern California. **Mail:** 1116 North Garfield Ave., Alhambra, Calif. (S)

Cozzens, Warren B., Sales Engineer. **Mail:** 220 Kedzie St., Evanston, Ill. (M)

Craddock, Douglas L., Radio and Theatre Operator. **Mail:** Leaksville, N.C. (A)

Crandall, Roland D., Animated Motion-Picture and Television Cartoons. **Mail:** 31 Heusted Dr., Old Greenwich, Conn. (A)

Cravens, Charles, University of Southern California. **Mail:** 942 W. 34 St., Los Angeles 7, Calif. **(S)**

Cummings, Carol, University of Southern California. **Mail:** 1215 Lodi Pl., Los Angeles 38, Calif. **(S)**

Cummings, George, Film Technician, Peerless Laboratories, 55 Dell Park Ave., Toronto, Ontario, Canada. **(A)**

Dahgdevirian, Charles, Laboratory Film Technician, Acme Film Laboratory, Inc. **Mail:** 4735 Oakwood Ave., Los Angeles 4, Calif. **(A)**

Davis, Jesse F., Cameraman, Cutter, 1790 Winona Blvd., Los Angeles 27, Calif. **(A)**

De Angelis, Maj. Luigi, Motion-Picture Cameraman and Producer, U.S. Air Force. **Mail:** 7208 La Presa Dr., Hollywood 28, Calif. **(A)**

Dembo, Samuel, 871 Seventh Ave., New York 19, N.Y. **(A)**

Dixon, Thomas L., Color Film Duplication, Sawyers Inc., Box 490, Portland, Ore. **(A)**

Dodge, George F., University of Southern California. **Mail:** 8000 Honey Dr., Los Angeles 46, Calif. **(S)**

Donaldson, Wallace C., Cameraman, Canadian Television Films, 53 Yonge St., Toronto, Ontario, Canada. **(A)**

Dorsey, Harry, University of Southern California. **Mail:** 833 W. 28 St., Los Angeles 7, Calif. **(S)**

Doughty, E. E., Laboratory Technician, General Films Laboratory Corp. **Mail:** 4238 Riverton Ave., North Hollywood, Calif. **(A)**

Dzur, Albert A., University of Southern California. **Mail:** 1043 W. 35 St., Los Angeles, Calif. **(S)**

Dzur, Carolyn Crage, University of Southern California. **Mail:** 1043 W. 35 St., Los Angeles, Calif. **(S)**

Eastwood, Clive, Professional Engineer, Radio Station CFRB, 37 Bloor St., West, Toronto, Ontario, Canada. **(A)**

Eberenz, Robert W., Motion-Picture Projectionist and Sound Technician, W. S. Butterfield Theatres, Inc. **Mail:** 1023 Martin St., Jackson, Mich. **(A)**

Ely, Julian B., University of California at Los Angeles. **Mail:** 1738 Bentley Ave., Los Angeles 25, Calif. **(S)**

Engelberg, Phil R., Laboratory Superintendent, Modern Movies Laboratories, Inc. **Mail:** 1147 North Coronado St., Los Angelés, Calif. **(M)**

Freeman, John Norman, Motion-Picture Cameraman, North American Aviation. **Mail.** 350 South Harvard Blvd., Los Angeles, Calif, **(A)**

French, Howard E., University of Southern California. **Mail:** 1138 W. 28 St., Los Angeles 7, Calif. **(S)**

Fulmer, Harold M., TV Broadcast Engineer, Wrather-Alvarez Broadcasting, Inc., KFMB-TV. **Mail:** 1214 Thomas Ave., San Diego 9, Calif **(A)**

Fulmis, Mike J., University of California at Los Angeles. **Mail:** 3297 Glendon Ave., Los Angeles, Calif. **(S)**

Garinger, Truman, University of Southern California. **Mail:** 1283 Browning Blvd., Los Angeles 37, Calif. **(S)**

Gebhart, Wilford W., Film Engineer, WSM-TV. **Mail:** 2000 Castleman Dr., Nashville, Tenn. **(M)**

Geier, Jane H., Layout Draftsman, Gilfillan Bros. **Mail:** 300 South Mariposa St., Burbank, Calif. **(A)**

George, Royford Verden, University of Southern California. **Mail:** 3437 Warwick Ave., Los Angeles, Calif. **(S)**

Gibson, William John, Motion-Picture Photographer, U.S. Air Force. **Mail:** 10531 Pinewood Ave., Tujunga, Calif. **(M)**

Glennon, Lawrence E., Jr., Industrial Engineer, Photographic Equipment, Signal Corps Pictorial Center. **Mail:** 15 Hatch Ter., Dobbs Ferry, N.Y. **(M)**

Gould, Arthur, Director, Cameraman, Naval Ordnance Test Station. **Mail:** 1253 North Orange Dr., Los Angeles, Calif. **(A)**

Grant, Arthur, Projectionist and Sound Technician, Metropolitan Theatres Co. **Mail:** P.O. Box 73231, Ascot Station, Los Angeles 3, Calif. **(A)**

Gregg, R. Richard, Manager, Sales and Installations, Fonda Corp., 550 West Colorado St., Glendale 4, Calif. **(M)**

Griffing, William E., Motion-Picture Producer. **Mail:** 105 Park Ave., East Orange, N.J. **(A)**

Gross, Edith, University of California at Los Angeles. **Mail:** 801 Levering Ave., Los Angeles 24, Calif. **(S)**

Hagopian, J. Michael, University of Southern California. **Mail:** 8000 Honey Dr., Hollywood 46, Calif. **(S)**

Hale, William Ballenger, University of Southern California. **Mail:** 804½ El Centro, Hollywood 38, Calif. **(S)**

Halligan, George, Film Editor, Producer, 6938 Coldwater Canyon, North Hollywood, Calif. **(A)**

Hansard, Robert L., Process Projection Engineer. **Mail:** 12607 Martha St., North Hollywood, Calif. **(M)**

Hanson, Harold E., Harolds Photo & TV, 1105 South Lake Ave., Sioux Falls, S.D. **(A)**

Harmony, Don, Timer and Printer, Geo. W. Colburn Laboratory. **Mail:** c/o K. H. Shuttle, 228 East Huron, Chicago 11, Ill. **(A)**

Harnett, David L., University of Southern California. **Mail:** 1140 W. 27 St., Los Angeles, Calif. **(S)**

Haun, James J., Motion-Picture Writer, Director, Engineer, North American Aviation. **Mail:** 5501 Orange Ave., Apt. 5, Long Beach, Calif. (A)

Hawes, Hildreth G., 16mm Producer, Maine Department of Agriculture. **Mail:** 3 Middle St., Hallowell, Me. (A)

Hawkins, Richard C., Teacher, University of California at Los Angeles. **Mail:** 1870½ Kelton, Los Angeles, Calif. (A)

Heath, Clyde, General Illustrator (Publications and Movies), Engineering Div., Navy Supply Depot. **Mail:** P.O. Box 122, Arlington, N.J. (M)

Heilmann, Philip Eugene, Gordos Corp. **Mail:** 19 Metlars La., Durham Park, New Brunswick, N.J. (A)

Henderson, Donald E., Production Assistant, Churchill-Wexler Film Productions. **Mail:** 14016 Gain St., Pacoima, Calif. (A)

Henderson, Ralph A., Sales Engineer, Minnesota Mining & Manufacturing Co., 900 Fauquier Ave., St. Paul, Minn. (M)

Hogsett, Alice E., University of Southern California. **Mail:** 6302 Beck Ave., North Hollywood, Calif. (S)

Hooper, R. B., Owner, Producer, Sonochrome Pictures. 2275 Glencoe St., Denver 7, Colo. (M)

Jackson, Joseph M., Department Manager, Motion-Picture Photographic Dept., Owens-Illinois Glass Co., 14th and Adams, Toledo 1, Ohio. (M)

Jewell, Stuart V., Cinematographer, Walt Disney Studios. **Mail:** 3848 Lomina Ave., Long Beach 8, Calif. (M)

Iohnson, William W., Camera Technician, Paramount Pictures Corp. **Mail:** 5880 Locksley Pl., Los Angeles 28, Calif. (A)

Jury, Harold William, Engineer-in-Charge, KNXT, Columbia Broadcasting System. **Mail:** 17260 Osborne St., Northridge, Calif. (M)

Kautzky, Rudolf W., Branch Manager, Altec Service Corp. **Mail:** 4106 Case St., Elmhurst 73, N.Y. (M)

Kendall, Richard S., University of Southern California. **Mail:** 1636 North Vistas, Hollywood 46, Calif. (S)

Kent, Dave, University of Southern California. **Mail:** 901 Exposition, Los Angeles 7, Calif. (S)

Kershner, Irvin, University of Southern California. **Mail:** 12225 Magnolia Blvd., North Hollywood, Calif. (S)

Ketchum, Northrop H., Kinescope Recording Laboratory Coordinator, National Broadcasting Co. **Mail:** 18552 Collins St., Tarzana, Calif. (A)

Keto, Jorma Raymond, Electro-Mechanical Engineer, National Bureau of Standards. **Mail:** 305 Dean Dr., Rockville, Md. (A)

King, Robert E., Technical Director, American Broadcasting Co. **Mail:** 3931 Prospect, Hollywood 27, Calif. (A)

Knudsen, Orlando Stephen, Manager, Visual Aids Production, Iowa State College, Alice Norton House, Ames, Iowa. (M)

Kontos, Spero L., Manager, Abbott Theatre Equipment Co., 1311 South Wabash Ave., Chicago, Ill. (A)

Lange, Peter, University of Southern California. **Mail:** 1815½ North Kingsley Dr., Hollywood 27, Calif. (S)

Larsen, Robert W., Production Manager, Mercury International Pictures, Inc., 6611 Santa Monica Blvd., Los Angeles, Calif. (M)

Larsen, Seth Beegle, Motion-Picture Film Editor, Processor, Larsen Co. **Mail:** 451 South Highland Ave., Los Angeles 36, Calif. (M)

Larson, Robert H., Chief Engineer, DuKane Corp., St. Charles, Ill. (M)

Legris, John, University of Southern California. **Mail:** 3827 Hepburn Ave., Los Angeles, Calif. (S)

Levy, Joseph, Film Technician, De Luxe Laboratories. **Mail:** 1346 Clay Ave., New York, N.Y. (A)

Lindenbaum Elaine, University of Southern California. **Mail:** 10472 Lindbrook Dr., Los Angeles 24, Calif. (S)

Linvall, A. R., Cinematographer, 16mm Technical, North American Aviation. **Mail:** 8606 Charloma Dr., Downey, Calif. (A)

Lutes, Harold R., Optical and Photographic Engineer, Owner, H. L. Instrument Co. **Mail:** 313 W. Valley Blvd., San Gabriel, Calif. (M)

Macauley, Mrs. Jan T., World Films, P.O. Box 72, Sierra Madre, Calif. (A)

Manoogian, Haig A., City College of New York. **Mail:** 130 Post Ave., New York 34, N.Y. (S)

Marker, Thomas P., In Charge, Motion-Picture Activities, Public Relations Dept., Chrysler Corp., 341 Massachusetts Ave., Detroit 31, Mich. (M)

Marshall, Lauriston C., Director of Research, Research Laboratory, Link-Belt Co., 220 South Belmont, Indianapolis, Ind. (M)

McCartney, Earl, Senior Project Engineer, Marine Engineering Division, Sperry Gyroscope. **Mail:** 2 Winding Rd., Rockville Centre, N.Y. (A)

McEvoy, Earl E., Motion-Picture Producer, 846 North Cahuenga Blvd., Hollywood 38, Calif. (A)

McNulty, Barney, University of California at Los Angeles. **Mail:** 4434 Morse Ave., North Hollywood, Calif. (S)

Meroz, Robert L., Field Service Engineer, De Vry Corp. **Mail:** 31 Albatross Rd., Levittown, L.I., N.Y. (A)

Merrick, M. J., Optical Engineer, Sawyer's Inc., P.O. Box 490, Portland 7, Ore. (M)

Miller, Clarence R., Service Engineer, RCA Service Co. **Mail:** P.O. Box 563, San Angelo, Tex. **(A)**

Miller, Henry J., University of Southern California. **Mail:** 4547½ St. Elmo Dr., Los Angeles 19, Calif. **(S)**

Moore, Russell G., District Manager, Bell & Howell Co. **Mail:** 8 Dojean Ct., Bergenfield, N.J. **(A)**

More, Jerry, University of Southern California. **Mail:** 669 W. 34 St., Los Angeles 7. **(S)**

Morin, Volney F., Resident Counsel, Technicolor Motion Picture Corp., 6311 Romaine St., Hollywood 38, Calif. **(A)**

Morris, Nelson, Producer, 538 Fifth Ave., New York, N.Y. **(M)**

Most, David, Instructor, New York University; Technical Consultant, Rush Instrument Co. **Mail:** 1716 Avenue T, Brooklyn 29, N.Y. **(A)**

Murray, James V., Assistant Cameraman, Technicolor Motion Pictures Inc. **Mail:** 5816 Whitsett, North Hollywood, Calif. **(A)**

Myers, Albert, Motion-Picture Camera Operator, Frank Wisbar Productions. **Mail:** 1936½ North Alexandria Ave., Los Angeles 27, Calif. **(A)**

Newell, John I., Motion-Picture Laboratory Technician, Western Cine Service, 114 E. Eighth Ave., Denver, Colo. **(A)**

Nishimura, Ryosuke, Technical Director, Konishiroku Photo Ind. Co., Ltd., Konishiroku, Kaken, 6838, Hinomachi, Tokyo, Japan. **(M)**

Noble, Richard, University of Southern California. **Mail:** 904 W. 28 St., Los Angeles 7, Calif. **(S)**

Pavel, Eric, Technical Director, Pan American Press & Film Ltd., Rua Xavier de Toledo, 264–7°, São Paulo, Brazil. **(M)**

Pera, Capt. William, Office of the Chief Signal Officer, Army Pictorial Service Division, Room 5A1058, Pentagon, Washington, D.C. **(A)**

Perlov, Arthur, Technical Director, Radio Record TV. **Mail:** Rua Monte Libano, 19, Nitero, E. do Rio, Brazil. **(A)**

Pierce, Raymond C., Jr., Assistant Cameraman, Unifilms, Inc., 146 E. 47 St., New York, N.Y. **(A)**

Pittard, R. L., University of Southern California. **Mail:** 3316 San Marino, Los Angeles, Calif. **(S)**

Poniatoff, Alexander M., President, Director of Engineering, Ampex Electric Corp. **Mail:** 561 Eaton Ave., Redwood City, Calif. **(A)**

Pontius, Frank E., Television Engineer (Kinescope Recording), National Broadcasting Co. **Mail:** 5255½ Hermitage Ave., North Hollywood, Calif. **(M)**

Poulis, William G., General Manager, Canadian Television Films, 53 Yonge St., Toronto, Ontario, Canada. **(A)**

Printy, Virgil M., Test Engineer, Technical Products Co. **Mail:** 11051 Emelita St., North Hollywood, Calif. **(M)**

Raguse, Elmer R., Sound Director, Hal Roach Studio. **Mail:** 1244 South Beverly Glen Blvd., Los Angeles 24, Calif. **(M)**

Ramsdell, Floyd A., Motion-Picture Producer, Worcester Film Corp., and Stereo Corp., 131 Central St., Worcester, Mass. **(M)**

Reynertson, Audrey Joan, University of California. **Mail:** 11678 Montana Ave., Los Angeles 49, Calif. **(S)**

Richter, George W., Laboratory Operator, Richter's Film Laboratory, 1715 North Mariposa Ave., Los Angeles 27, Calif. **(M)**

Robins, Wiley W., University of Southern California. **Mail:** 528 Ruberta Ave., Glendale 1, Calif. **(S)**

Robinson, Carl C., Photographic Chemist, Alexander Film Co. **Mail:** 815 East Dale St., Colorado Springs, Colo. **(M)**

Rose, Nicholas, Psychologist, University of Southern California. **Mail:** 5060 W. Twelfth, Los Angeles 19, Calif. **(A)**

Ross, John F. M., Graphic Associates Film Production Ltd., 1111 Bay St., Toronto, Ontario, Canada. **(A)**

Rummage, J. Reid, University of Southern California. **Mail:** 1637¼ Arapahoe St., Los Angeles 6, Calif. **(S)**

Rush, David H., Owner, Rush Instrument Co. **Mail:** 1 Fisher Dr., Mount Vernon, N.Y. **(A)**

Rutledge, Donovan L., Chief Photographer, Beech Aircraft Corp. **Mail:** 124 South Charles, Wichita 12, Kan. **(A)**

Sanders, Terry B., University of California at Los Angeles. **Mail:** 2881 Coldwater Canyon Dr., Beverly Hills, Calif. **(S)**

Sargent, Robert E., Television Engineer, American Broadcasting Co. **Mail:** 660 Ocean Ave., Richmond, Calif. **(A)**

Schnebel, Charles, University of California at Los Angeles. **Mail:** 1700 Manning, Los Angeles 24, Calif. **(S)**

Selsted, Walter T., Chief Engineer, Ampex Electric Corp. **Mail:** 3960 Martin Dr., San Mateo, Calif. **(A)**

Sherman, Reuel A., Director, Occupational Vision, Bausch & Lomb Optical Co., Rochester, N.Y. **(M)**

Siegmund, Walter P., Scientific Aide to Vice-President of Research, American Optical Co., Southbridge, Mass. **(A)**

Simon, Ernest M., Sound Engineer, Audio-Visual Department, Syracuse University. **Mail:** 950 East Livingston Ave., Columbus, Ohio. **(M)**

Smith, Donald P., Sales, Custom Projection Equipment and Screens, Commercial Picture Equipment, Inc. **Mail:** 1107 South Chase St., Wheaton, Ill. **(A)**

Smith, Harry R., Supervisor, Visual Education Branch, Department of Education, 244 College St., Toronto, Ontario, Canada. (A)

Smith, Sidney S., Electronic Design Engineer, Link Aviation, Inc. **Mail:** 517 Castle St., Geneva, N.Y. (M)

Snody, Robert R., Motion-Picture Unit Production Manager and Director, 20th Century-Fox Films, Via Goito 60, Rome, Italy. (M)

Solomon, Berel David, Electronics Engineer, Physicist, Physics Dept., University of Miami. **Mail:** 1301 Lenox Ave., Miami Beach 39, Fla. (A)

Stevens, Clarence T., Recording Engineer, Moulin Studios, 181 Second St., San Francisco 5, Calif. (M)

Stockert, Henry A., University of Southern California. **Mail:** Apt. B, 921 South Adams, Glendale 5, Calif. (S)

Stringfellow, William M., Chief Engineer, WSPD-AM, FM, TV, Storer Broadcasting Co., 136 Huron St., Toledo, Ohio. (M)

Stuber, F. L., Maine Employment Security Training Officer. **Mail:** R #1, River Rd., Richmond, Me. (A)

Sutherland, J. Paul, Motion-Picture Technician, 189 Sutherland Dr., Toronto, Ontario, Canada. (A)

Swink, George E., Assistant Head, Editorial Dept., RKO Radio Pictures, Inc., 780 North Gower St., Hollywood, Calif. (A)

Syracusa, Rudolf, Laboratory Technician, Tricolor Laboratories. **Mail:** 6332½ Crenshaw, Los Angeles 43, Calif. (A)

Tarr, Eric Gordon, University of Southern California. **Mail:** 4507 Tenth Ave., Los Angeles 43, Calif. (S)

Tavris, Eugene, University of Southern California. **Mail:** 1812 Western, Los Angeles, Calif. (S)

Thie, Dean A., University of Southern California. **Mail:** 4035 W. 60 St., Los Angeles 43, Calif. (S)

Tremper, Richard E., Motion-Picture Writer and Director, North American Aviation. **Mail:** 900 Luray St., Long Beach 7, Calif. (A)

Tschume, George G., Manager, Photographic Sales Dept., Scientific Instrument Division, Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N.Y. (M)

Urban, Jack C., Professional Engineer (Mechanical). **Mail:** 10533 Sarah St., North Hollywood, Calif. (M)

Vellani, Antonio, University of Southern California. **Mail:** 2036 North Beachwood, Hollywood 28, Calif. (S)

Vlack, Robert C., University of Southern California. **Mail:** 2258 Luana La., Montrose, Calif. (S)

Ward, Richard H., Television Technician, WRGB, General Electric Co., 60 Washington Ave., Schenectady, N.Y. (A)

Watkins, Richard, Northwestern University. **Mail:** 4654 Milwaukee Ave., Chicago 30, Ill. (S)

Wells, Clifford, Machinist, Ace Film Laboratories, Inc. **Mail:** 2105 Avenue Z, Brooklyn 35, N.Y. (A)

West, George R., University of Southern California. **Mail:** 5629 Ensign St., North Hollywood, Calif. (S)

Widing, C. George, Laboratory Engineer. **Mail:** 8764 Beverly Blvd., Los Angeles, Calif. (A)

Williams, Fred G., Assistant General Manager and Vice-President, Consolidated Amusement Co., Ltd., 25 Taylor St., Suite 706–8, San Francisco 2, Calif. (A)

Wisniewski, Ray, University of Southern California. **Mail:** 804½ El Centro, Los Angeles, Calif. (S)

Wolfman, Augustus, Editor, Photography Publishing Corp., 251 Fourth Ave., New York 10, N.Y. (A)

Wood, Capt. Richard A., Army Pictorial, Signal Corps. **Mail:** 3311 Fordham Rd., Academy Gardens, Philadelphia 14, Pa. (A)

Woolery, Adrian D., Motion-Picture Producer, Playhouse Pictures, 749 North Highland Ave., Los Angeles, Calif. (A)

Yamin, Robert H., TV Productions, ZIV Television Programs, 5255 Clinton St., Los Angeles, Calif. (A)

Young, John W., Lecturer, Motion-Picture Division, University of California. **Mail:** 10551 Scenario La., Los Angeles 24, Calif. (A)

Zacarias, Ruben, University of Southern California. **Mail:** 4317 Kenwood Ave., Los Angeles 37, Calif. (S)

Zuber, James, University of Southern California. **Mail:** 10415 South Noover St., Los Angeles, Calif. (S)

DECEASED

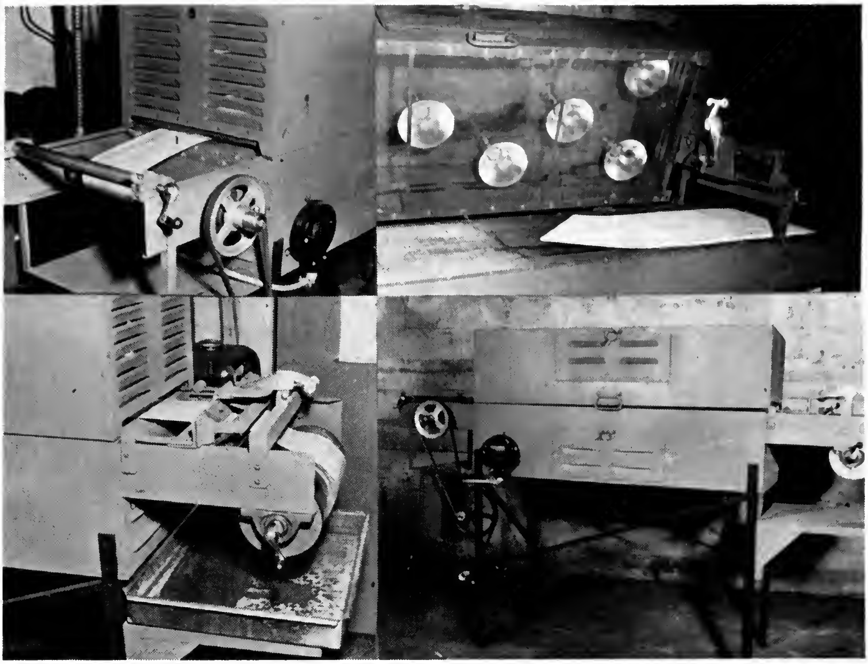
Griffin, Herbert, Vice-President, International Projector Corp. **Mail:** 1615 Cordova St., Los Angeles 7, Calif. (F)

Mann, Riborg G., Chief Engineer, Pathe News, Inc., 625 Madison Ave., New York 22, N.Y. (M)

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal.*

New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.



The Metlen Dryer, to process photographic recording paper more quickly, rather than more slowly, than it is used, has been developed and placed on the market by the Metlen Manufacturing Co., P.O. Box 2186, Seattle, Wash. Formerly, 200-ft lengths of from one to 20 rolls were exposed in an 8-hr day, but took 2 to 3 days to process. This dryer will dry a 200-ft roll of photographic recording paper in 10 to 16 min, depending on the width and type of paper.

After being developed, the wet paper is wound on a large spool at the receiving end of the dryer. From this spool the paper is run through squeegies and then between the drying chambers to a rewind core, which is driven by a 1/10-hp 110-v electric motor with a resistor control to determine drying speed, regulated according to width and quality of paper. After it is dried the roll of paper is slipped off the core.

All metal parts of the squeegies which remove the surplus water from the paper are of stainless steel. The drying chambers between which the paper travels have an arrangement of eighteen 375-w 110-v commercial drying bulbs. The paper travels between these two heat chambers held in place by a drying screen of fine-mesh stainless steel. The top half of the dryer is fluted so as to create heat and moisture circulation, vaporizing the moisture and removing it with the excess heat from the drying chamber. The free flow of moisture and heat from the dryer results in the short drying period.

The Kelly Cine Calculator is designed to provide in compact and easily operable form a means for establishing such 35mm cinematography data as these: (on front side, shown above) hyperfocal distance and depth of focus; (on reverse side, not shown) film speed per second; aperture scales (T-stops have been added for the users' convenience and are based on existing Technicolor-to-*f* stop values; it is not claimed that they necessarily represent absolute transmission values); filter factors, camera speed-to-aperture; shutter angle-to-aperture; field of view; key-light and many other factors. The Calculator comes in two models: one for 35mm which is also useful for Leica, Contax and minicam fans; and another for 8-16mm. List price is $3.95, including complete instruction manuals. Made in England, sole distributors for U.S. and South America are Florman & Babb, 70 W. 45 St., New York 36.

The F &B Film Footage Counter has been introduced by Florman and Babb, 70 West 45th St., New York 36, N.Y. The dual model is a re-settable, synchronous film counter in 16mm and 35mm, on which either one or both may be selected by a switch. Monitor lights indicate whether the counter is in operation. With another selector, the unit can be switched to either "Sync" or "Line" position. In "Sync" position, the selector by-passes other switches in the unit, thus giving free way and interlocking with the synchronous power supplied by a projector, a dubber, etc. In "Line" position the unit will be manually started and stopped by a small On-Off switch.

On the back plate of the unit, a standard-sized receptacle will furnish a 110-v 60-cycle sync line for a minute and seconds counter, cueing signal, script reading light or other accessories.

In order to assure a smooth and quiet drive, the high torque, low-speed synchronous motors are nylon geared and equipped with special lubricants. The unit starts and stops within 1 cycle ($^1/_{60}$ sec).

Florman & Babb are also introducing small single 16mm and 35mm footage counters with simplified construction, as well as a time counter unit which reads up to 99 min and 59 sec. This time counter can be plugged in to any of the dual or single footage counter units for complete footage and time readings.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, and there is no charge to the member.

Positions Available

Wanted: Motion-picture processing technicians for employment at U.S. Naval Ordnance Test Station, China Lake, Calif. Operators of Models 10 and 20 Houston motion-picture processing machines, and operators of Bell & Howell Models "D" and "J" motion-picture printers are needed. Civil Service positions — $3,410 per annum base pay. Family housing limited; single persons preferred. Obtain Form 57 from any U.S. Post Office, fill out in detail, and mail to Carlos H. Elmer, 410B Forrestal, China Lake, Calif.

Senior Engineer with leading supplier of motion-picture and TV equipment is looking for an associate in the development of film and tape handling equipment and other fine electromechanical devices. Give résumé of professional experience and range of interest and accomplishments by letter to W. R. Isom, 1203 Collings Ave., Oaklyn, N.J.

Wanted: Two design engineers, must be familiar with camera and precision instrument design. A working knowledge of machine shop practice essential. Salaries commensurate with ability. Send résumé of experience and personal details in letter to: Land-Air Inc., 900 Pennsylvania Ave., Alamogordo, N.M.

Wanted: Optical Engineer for permanent position with manufacturer of a wide variety of optics including camera objectives, projector, microscope and telescope optics, etc. Position involves design, development and production engineering. Send résumé of training and experience to Simpson Optical Mfg. Co., 3200 W. Carroll Ave., Chicago 24, Ill.

Wanted: Personnel to fill the 4 classifications listed below, by the Employment Office, Atten: EWACER, Wright-Patterson Air Force Base, Ohio:

Film Editor, GS-9: Must have 5 yrs. experience in one or more phases of motion-picture production. Experience must include at least 1½ yrs. motion-picture film editing with responsibility for synchronization of picture, narration, dialogue, background music, sound effects, titles, etc. $5060 yr.

Photographic Processing Technician (Color) GS-7: 6 yrs. progressively responsible experience in motion-picture photography and/or photographic laboratory work, involving essential operation of film processing. Eighteen months of this experience must have involved processing of color film. $4205 yr.

Photographic Processing Technician (Black-and-White) GS-7: 6 yrs. progressively responsible experience in motion-picture photography and/or photographic laboratory work, involving essential operation of film processing. $4205 yr.

Photographic Processing Technician (Black-and-White) GS-5: 2½ yrs. progressively responsible experience in motion-picture photography and/or photographic laboratory work, involving essential operation of film processing. $3410 yr.

Positions Wanted

TV Cameraman-Director, year's experience as cameraman, asst. stage manager and lighting director; manager, small studio and director of 15-min fill-in TV shows, up to 5 shows weekly, mostly educational TV programs, also daily illustrated newscast, at LR3 Radio Belgrano TV, Buenos Aires, Argentina. Experienced in still and live commercials. Born in U.S., age 26, single, B.A. Hunter College (1951). Veteran, World War II. Desires position with TV station anywhere in U.S. or Latin America; willing to travel. Fluent Spanish. Particularly interested in educational TV, nevertheless, will accept any type of TV work related to experience offered. References, résumé, etc., available on request. Write *airmail* to Stanley E. Lustberg, Jose Everisto Uriburu 1551, Buenos Aires, Argentina.

Picture Optical Printer Available With Operator: Modern complete machine 35mm to 35mm and 16mm to 35mm using Acme Projector and Camera, registration to 0.0001 in., including many accessories, synchronizers, etc. Over 200 TV commercials, many features and blowups in color and B&W. Represents $20,000 investment. Owner-operator has long experience with Hollywood major studios. Can double as cameraman. Reasonable. Contact Wm. G. Heckler, 245 West 55 St., New York, N.Y. Phone: Plaza 7-3868.

Meetings

WESCON (Western Electronic Show & Convention), Aug. 19–21, Civic Auditorium, San Francisco

Biological Photographic Association, 23d Annual Meeting, Aug. 31–Sept. 3, Hotel Statler, Los Angeles, Calif.

Illuminating Engineering Society, National Technical Conference, Sept. 14–18, Hotel Commodore, New York, N.Y.

The Royal Photographic Society's Centenary, International Conference on the Science and Applications of Photography, Sept. 19–25, London, England

National Electronics Conference, 9th Annual Conference, Sept. 28–30, Hotel Sherman, Chicago

74th Semiannual Convention of the SMPTE, Oct. 5–9, Hotel Statler, New York.

Audio Engineering Society, Fifth Annual Convention, Oct. 14–17, Hotel New Yorker, New York, N.Y.

Theatre Equipment and Supply Manufacturers' Association Convention (in conjunction with Theatre Equipment Dealers' Association and Theatre Owners of America), Oct. 31–Nov. 4, Conrad Hilton Hotel, Chicago, Ill.

Theatre Owners of America, Annual Convention and Trade Show, Nov. 1–5, Chicago, Ill.

National Electrical Manufacturers Association, Nov. 9–12 Haddon Hall Hotel, Atlantic City, N.J.

The American Society of Mechanical Engineers, Annual Meeting, Nov. 29–Dec. 4, Statler Hotel, N.Y.

American Institute of Electrical Engineers, Winter General Meeting, Jan. 18–22, 1954, New York

National Electrical Manufacturers Assn., Mar. 8–11, 1954, Edgewater Beach Hotel, Chicago, Ill.

75th Semiannual Convention of the SMPTE, May 3–7, 1954, Hotel Statler, Washington

76th Semiannual Convention of the SMPTE, Oct. 18–22, 1954 (next year), Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955, Drake Hotel, Chicago

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955, Lake Placid Club, Essex County, N.Y.

The Seventh Congress of the International Scientific Film Association will be held September 18–27 in the National Film Theatre and Royal Festival Hall, London S.E.1. A Scientific Film Festival will be held, and in addition, meetings will be held by the Permanent Committees on Medical, Research, Technical and Industrial Films. There will be special sessions on the technique and application of films in medicine.

Image Gradation, Graininess and Sharpness in Television and Motion-Picture Systems

Part III: The Grain Structure of Television Images

By OTTO H. SCHADE

CONTENTS

Presented by Otto H. Schade, Tube Dept., Radio Corporation of America, Harrison, N.J., in part on October 15, 1951, at the Society's Convention at Hollywood, Calif., and on April 28, 1953, at the Society's Convention at Los Angeles.

Note: Part I of this paper, "Image structure and transfer characteristics," was published in this *Journal* in February 1951, pp. 137–171; and Part II, "The grain structure of motion picture images — an analysis of deviations and fluctuations of the sample number," in March 1952, pp. 181–222.

(This paper was received first on March 3, 1953, and in revised form on June 5, 1953.)

SYMBOLS

Note: Peak values are designated by a peak sign over a symbol $\hat{I}$; and average or mean values by a horizontal bar, $\bar{n}$. When used with $\bar{N}_e$-values, the bar indicates the geometric mean for two coordinates.

- a Area of sampling aperture
- a_e Equivalent sampling aperture
- A Frame area
- b Blanking factor (See Eqs. (61) and (72))
- B Luminance
- c A constant
- C Capacitance
- d Viewing distance
- $\tilde{e}$ Noise voltage
- E_1 Exposure (unit: meter candle seconds)
- E Signal voltage
- $[\tilde{E}]$ Rms noise voltage
- f Frequency: $f(x,y)$ a function of x and y
- Δf Theoretical rectangular frequency channel (Eq. (63))
- Δf_e Noise-equivalent passband of electrical elements or systems
- h Horizontal dimension of equivalent sampling aperture or index for horizontal coordinate
- H Horizontal dimension of picture frame
- $\tilde{\imath}$ Noise current
- I Intensity or current
- K A constant
- l Unit of length
- m Horizontal bandwidth factor of electrical circuits (Eq. (79))
- N Line number — number of half-wavelengths of line- or sine-wave patterns per length unit
- N_c Limiting resolution, $N_{c(b)}$ limiting resolution of aperture system following raster process
- N_e Equivalent passband (Eqs. (22) to (28) Part II)
- $\bar{N}_e$ Equivalent passband of an asymmetric aperture (Eq. (23) Part II)
- $N_{e(a)}$ Equivalent passband of all apertures preceding and including analyzing aperture of raster process
- $N_{e(b)}$ Equivalent passband of all apertures following and including synthesizing aperture of raster process
- $\bar{N}_{e(f)}$ = $(N_{c(h)}n_r)^{\frac{1}{2}}$ Equivalent passband of theoretical television channel (Eq. (64))
- $\bar{N}_{e(m)}$ = $(N_{e(h)}N_{e(v)})^{\frac{1}{2}}$ Equivalent optical passband of measuring aperture δ_m
- $\bar{N}_{e(s)}$ = $(N_{e(h)}N_{e(v)})_s^{\frac{1}{2}}$ Equivalent optical passband of system between origin of deviations and point of observation
- n Number of particles or samples inside of sampling area
- n_r Raster constant, number of points or lines in length unit
- n_s Number of scanning lines including vertical blanking period (Eq. (62))
- q_e Electron charge
- Q_f Frame charge (Eq. (71))
- r_ψ Sine-wave response factor of an aperture (Eq. (18))
- $r_{\tilde{e}}$ Electrical sine-wave response factor (Eq. (65))
- $r_{\psi a}$ Response factor of analyzing aperture (including preceding apertures)
- $r_{\psi b}$ Response factor of synthesizing aperture (including following apertures)
- $[r_\psi]$ Rms response factor
- R Resistance
- $[R]$ Signal-to-rms-deviation ratio, static value in a single image frame (Eq. (13) Part II)
- $[R]_m$ Reference signal-to-deviation ratio measured at the source with a known aperture δ_m
- $[R]_s$ Signal-to-deviation ratio of system
- s Length of side of square aperture, or storage factor
- t Time interval
- T_f Frame time
- v Vertical dimension of equivalent sampling aperture or index for vertical coordinate
- V Vertical frame dimension
- x,y Coordinates, x = coordinate in the direction of scanning
- Y Amplitude
- α $=(N_{e(s)}/N_c)_h$ Horizontal bandwidth factor (Eq. (66))
- β $=N_{e(s)v}/n_r$ Vertical bandwidth factor (Eq. (67))
- $(\alpha\beta)^{\frac{1}{2}}$ = $(\bar{N}_{e(s)}/(N_{c(h)}n_r)^{\frac{1}{2}}$ Optical bandwidth factor (Eq. (68))
- γ Constant gamma
- $\dot{\gamma}$ Point gamma, definition in Part I, p. 145
- $\dot{\gamma}_s$ Point gamma of system at a particular signal level between origin of deviations and point of observation
- δ Characteristic aperture diameter
- δ_f Equivalent optical aperture of theoretical television channel (Fig. 80)
- ϵ Base of natural logarithm
- τ Transmittance
- σ Relative deviation (Eqs. (13) to (17) Part II)
- θ Phase displacement between sample amplitude and crest intensity $\hat{I}_N$ (Fig. 69)
- ψ Flux
- $[\tilde{\psi}]$ Rms value of variational (a-c) flux (see Eq. (20))

SUMMARY OF PART III

The analysis of grain structures in imaging systems containing a point- or line-raster process requires evaluation of the sine-wave response in two coordinates. The characteristics of the raster process are developed by a Fourier analysis of the optical image. The sine-wave response perpendicular to the raster lines (for example the vertical sine-wave response of a television system) is shown to contain in general a carrier wave, the normal aperture response to sine-wave test signals, and a series of sum-and-difference components with magnitudes depending on the aperture response products of the analyzing and synthesizing apertures preceding and following the raster process (camera tube and kinescope in television systems). A graphic representation of the raster equation (Fig. 70) shows at a glance the number and magnitude of the sine-wave components for any combination of apertures used with the raster process. The application of the aperture theory developed in Part II yields an equivalent optical aperture (Fig. 80) and equivalent passband (Eq. (64)) for the theoretical television channel. The evaluation of the horizontal sine-wave response of electro-optical systems containing electrical and optical elements is simplified by establishing normalized characteristics for the sine-wave response, equivalent passband, aperture cross section, and edge transition of a variety of electrical response characteristics (including aperture correction) in cascade with optical apertures. Because of their general character and use in the evaluation and design of television systems, the range of parameters has been extended beyond the cases used in examples.

In normalized units equivalent passbands (horizontal and vertical) of electrooptical systems are specified by bandwidth factors (α and β), which are ratios of the equivalent passband of the system to the theoretical passbands $N_{c(h)}$ and n_r of the television channel (section D_1). These bandwidth factors emerge as significant parameters specifying the characteristics of the system.

The translation of electrical noise levels into optical deviations in a television frame is now readily accomplished, permitting evaluation of granularity by the methods discussed in Part II. It is shown that the electrical signal-to-noise ratios usually quoted for television systems have by themselves little meaning when television grain structures are compared, because the transfer characteristics and apertures of the system cause pronounced changes in signal-to-deviation ratios and the amplitude of the sine-wave components contained in optical deviations of a television picture frame. It is concluded that an adequate description of granularity in television and motion-picture frames requires specification of the sine-wave spectrum and signal-to-deviation ratio in the retinal image as a function of luminance and for a specified viewing distance. An assessment of the perception of deviations throughout the luminance range of motion pictures and television images can be made by introducing the characteristic of threshold signal-to-deviation ratios as a reference level.

A. REVIEW OF PRINCIPLES

The principles and method developed in the analysis of motion-picture granularity in Part II of this paper can be applied to all imaging systems and will be summarized briefly. Random fluctuations of luminance in motion-picture or television images cause the appearance of a moving granular structure. In a single picture frame representing a constant light level the structure is stationary

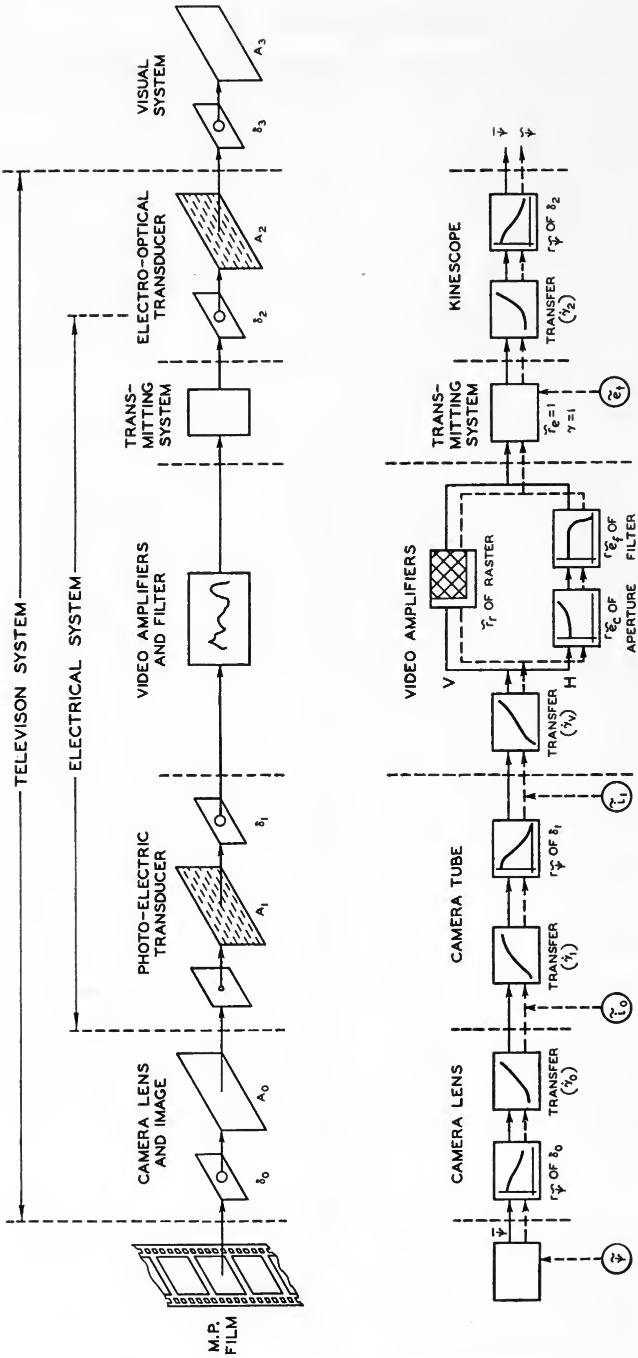


Fig. 65. Block diagram of television process and sources of random deviations.

and the luminance variations are *static deviations* from the average luminance which is the *optical signal.*

Optical signals and deviations are measured by taking samples of the image flux with an aperture. The average value of the sample readings is the signal. The relative magnitude of the deviations is expressed by the *relative deviation* σ or its reciprocal, the *signal-to-rms deviation ratio* $[R]$. When the deviations are random (see Part II for definition) the value $[R]$ measured at the source of deviations is directly proportional to the one-half power of the effective area a_e of the sampling aperture as stated by

$$[R] = 1/\sigma = (\bar{n}_0 a_e)^{\frac{1}{2}}$$

where $\bar{n}_0$ specifies the mean "particle" density in the random structure at the source. The effective sampling area of practical image-forming devices or systems can be determined from the geometry of their point image (see Part II) or from the total sine-wave energy response of the point image, obtained by a Fourier analysis of a test image such as a single sharp line, a single-edge transition, a random grain structure, or from sine-wave test patterns. The last two methods mentioned, particularly the method using sine-wave test patterns with variable line number, are known from analogous electrical measurements to be most accurate because of the high energy level of the observed signals and the simplicity of evaluation. In sine-wave response measurements the point image is regarded as an "aperture" of unknown geometry which is made to scan a series of constant-energy sine-wave test patterns. The total relative sine-wave energy of the aperture response characteristic is specified by a single number N_e interpreted as an *equivalent passband.* The reciprocal of this measure K/N_e specifies the diameter of the desired *equivalent sampling aperture* (see Table VII, Part II). The point images of practical devices are often asymmetric. In this case the equivalent sampling aperture can be specified as a rectangle with the dimensions h and v, which are the reciprocals of two equivalents:

$$a_e = hv = [Ne_{(h)}Ne_{(v)}]^{-1} \qquad (51)$$

The asymmetric point image is described by two sine-wave response characteristics in rectangular coordinates (H and V) and their corresponding equivalent passbands $N_{e(h)}$ and $N_{e(v)}$.

The signal-to-deviation ratio $[R]$ can now be stated in the forms

$$[R] = \bar{n}_0^{\frac{1}{2}}/[N_{e(h)}N_{e(v)}]^{\frac{1}{2}}$$

$$[R] = \bar{n}_0^{\frac{1}{2}}/\bar{N}_e \qquad (52)$$

where $\bar{N}_e$ is the geometric mean of the two equivalent passbands.

The particle density $\bar{n}_0$ *at the source* can be determined by a count of the number of particles (grains or electrons) in a unit area of the random structure in which the deviations originate. When this is impractical, $\bar{n}_0$ is obtained from a reference value $[R]_m$ measured or computed with an aperture of known area a_m or equivalent passband $\bar{N}_{e(m)}$.

The actual signal-to-deviation ratio $[R]_s$ at any one point in the imaging system can then be computed accurately from the aperture ratio (Eq. (37) in Part II) which, stated in terms of N_e-values, has the form

$$[R]_s = [R]_m(\bar{N}_{e(m)}/\bar{N}_{e(s)})/\dot{\gamma}_s \qquad (53)$$

where

$[R]_m$ = signal-to-deviation ratio at the origin of deviations, measured with an aperture of equivalent passband $\bar{N}_{e(m)}$

$\bar{N}_{e(m)} = (N_{e(h)}\,N_{e(v)})_m^{\frac{1}{2}}$ = equivalent optical passband of measuring aperture

$\bar{N}_{e(s)} = (N_{e(h)}N_{e(v)})_s^{\frac{1}{2}}$ = equivalent optical passband of system aperture between origin of deviations and point of observation

$\dot{\gamma}_s$ = overall transfer ratio or "point gamma" of system elements at the particular signal intensity between origin of deviations and point of observation.

The analysis of optical deviations in television images requires a translation of television system parameters and characteristics into equivalent optical units. A schematic representation of a television process is shown in Fig. 65. The light flux in the optical image A_0 formed by the camera lens is transduced into an electrical image A_1 in the television camera tube. The charge image A_1 is scanned by an aperture δ_1 along a system of parallel lines termed a *line raster*. The aperture δ_1 is the electron beam of the camera tube which transduces the electrical aperture flux into video signals. The electrical signals are amplified, limited by electrical filters, transmitted and again transduced into light-flux variations by the aperture δ_2 of an electro-optical transducer (kinescope) scanning the frame area A_2. The two scanning apertures δ_1 and δ_2 are moved with uniform velocity and in synchronism over the respective frame areas. Like optical apertures, these scanning apertures have two dimensions, and their response is readily described by normal sine-wave response characteristics and equivalent passbands. New elements in the imaging system requiring evaluation in terms of optical response characteristics are the *line raster* and the electrical system of amplifiers and low-pass filters.

Luminance deviations in a television frame may be caused by a number of sources located at different points in the system (see Fig. 65). When the deviations originate in a preceding photographic process, the television system is an aperture process transferring a two-dimensional granular structure. Deviations originating in electrical elements, however, may not be associated with the transferred image. Electron sources such as the cathodes of electron guns or amplifier tubes continually produce random fluctuations in the flow of electrons, which are arranged and displayed artificially in two dimensions by the scanning process. The resulting luminance deviations in the frame area may, however, be regarded as the image of a random particle structure scanned with a hypothetical camera and measured with a theoretical sampling aperture $\delta_{(f)}$ which will be found to have a specific value given by the system constants. With this concept all cases can be treated by one method.

B. RASTER PROCESSES

1. The Raster Constant (n_r)

The formation of images by lenses or optical systems is continuous in both coordinates of the image area. It is, therefore, permissible to determine signals and deviations from a limited number of sample readings, because every point in the image area undergoes an aperture process. The aperture shape becomes indistinguishable in areas of constant luminance. In the presence of deviations, the steady "signal" flux can be considered as a "carrier" flux of constant intensity $\bar{I}$ "modulated" by random deviations.

Printing, facsimile and television are sampling processes in which the number of aperture positions is finite in one or both coordinates of the image frame. The image flux is no longer continuous in two coordinates but contains periodic components. An arrangement limiting aperture positions to a fixed number of uniformly spaced points in the image frame is termed a *point raster;* an arrangement providing continuous aperture positions along uniformly spaced parallel lines is termed a *line raster. The "raster" constant n_r specifies the number of aperture positions in the length unit of a geometric arrangement of points or lines;* it does not specify the dimensions of the "points" or "lines" themselves which are determined by the geometry of the sampling apertures used with the raster process.

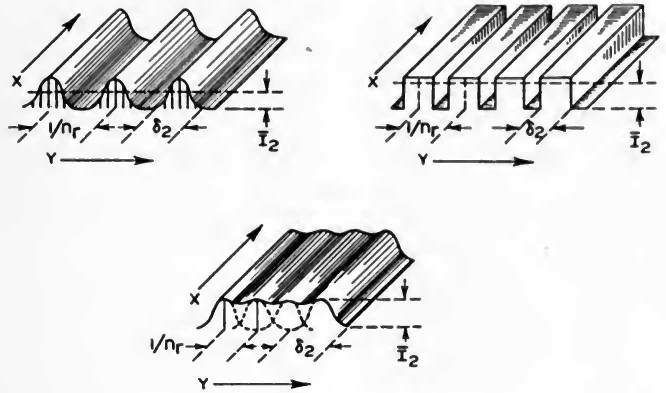


Fig. 66. Intensity distribution and "carrier" waves in the *y*-coordinate of line-rasters.

2. Carrier Wave and Line Structure

A line raster limits the number of aperture positions perpendicular to the raster lines. Areas of constant luminance are reproduced by the aperture δ_2 as a flux pattern in which the intensity is constant in the direction x parallel to the raster lines but contains a more or less pronounced periodic component in the y-coordinate defined as the coordinate perpendicular to the raster lines (Fig. 66). The following analysis of conditions in the y-coordinate of a line raster applies to optical as well as television processes† and also to point rasters which cause periodic components in both x- and y-coordinates. (In television images the coordinate Y is identical with the vertical coordinate V of the image frame.)

The periodic component can be regarded as a constant *carrier wave* added by the raster to the continuous carrier flux of a normal aperture process. The signal flux from the analyzing aperture δ_1 determines the average intensity level $\bar{I}$, i.e., the scale factor of the image flux. It is seen by inspection of Fig. 66 that the length of the carrier wave is the reciprocal of the raster constant: $\Delta y = 1/n_r$, while waveform and relative amplitude of the carrier wave are determined by the geometry of the synthesizing aperture δ_2.

A Fourier analysis of this "pulse carrier wave" shows that the intensity distribution $I_{(y)} = f(y)$ contains the constant signal term $\bar{I}$ and a series of harmonic cosine waves:

$$I_y = \bar{I}[1 + \sum_p 2r_{\bar{\psi}(pn_r)} \cos p\pi y n_r] \quad (54)$$

$(p = 2, 4, 6, \ldots)$

The cosine terms specify the harmonic components of the carrier wave, which have (television) line numbers $N_{r1} = 2n_r$, $N_{r2} = 4n_r$, $N_{r3} = 6n_r$, ... Their relative intensities are specified by coefficients which are the *sine-wave response factors* $r_{\bar{\psi}(\ldots)}$ in the y-coordinate of the particular aperture δ_2 at the line numbers of corresponding carrier harmonics. The cosine-wave components are in phase at the aperture center (on the raster line) when the aperture has axial symmetry† and its response decreases asymptotically to zero. When the response characteristic has an oscillatory form (compare Figs. 41 and 42 of Part II), the phase may reverse at each zero re-

† A two-dimensional Fourier analysis of the television picture was presented in an early paper by Mertz and Gray.[1]

† Apertures with asymmetric cross sections introduce phase shifts between cosine terms and will be discussed in Part IV.

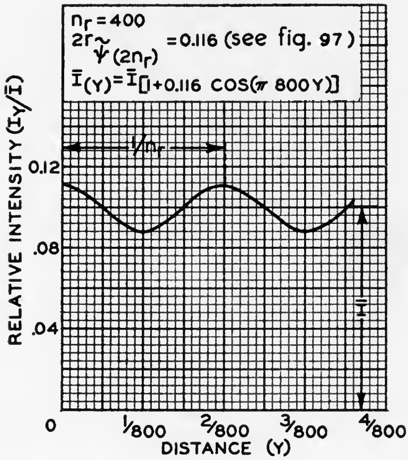


Fig. 67. Intensity distribution in *y*-coordinate of raster process with kinescope aperture $\delta_2 > 1/n_r$ passing only one cosine term of the carrier wave.

sponse point. Examples illustrating a numerical synthesis of the intensity distribution expressed by Eq. (54) are shown in Figs. 67 and 68. Equation (54) establishes a direct relation between the geometry of the *line image* and the sine-wave response characteristic of the line-generating point image. For the purpose of reconstructing an aperture cross section (i.e. an isolated line) from its sine-wave spectrum the fundamental component $N_{r1} = 2n_r$ in Eq. (54) is given a low value for which the bracketed terms of Eq. (54) equal zero at the distance $y = \frac{1}{2}n_r$. This condition is obtained when

$$2(r_{\psi(2n_r)} - r_{\psi(4n_r)} + r_{\psi(6n_r)} - \ldots) = 1 \quad (55)$$

A fundamental component $N_r = 2n_r = 200$ lines was used for the aperture synthesis (Fig. 68) from the sine-wave response characteristic (Fig. 95).

The presence of a pronounced line structure in the image is highly undesirable. Perfect continuity is restored when none of the carrier-wave components are reproduced by the aperture δ_2, i.e., when the aperture response is zero at line numbers which are integral multiples of $2n_r$. Practical imaging devices usually have an aperiodic response characteristic. In some cases the response has nonintegral zeros, but the response is usually low beyond the first zero. A substantially continuous or "flat" field is, therefore, obtained when

$$r_{\psi(2n_r)} \lesssim 0.005 \quad (56)$$

This response factor causes a ripple amplitude of 1%, i.e., a peak-to-peak intensity variation of 2%. The aperture process δ_2 in the reproducing device (kinescope) is followed by other imaging processes, for example by the process of vision or by a photographic process. It is, therefore, unnecessary to restrict the response of the aperture δ_2 alone by Eq. (56) but rather the overall sine-wave response $r_{\psi b}$ of the aperture system following the raster process (indicated by the index *b*).

The flat-field condition specified by Eq. (56) may be stated in the form

$$N_{c(b)} \lesssim 2n_r \quad (56a)$$

Assume for example that a standard 35-mm motion-picture process (Table IX (1 to 4), Part II) which has a limiting resolution N_c of approximately 1100 lines, is used for video recording. It follows from Eq. (56a) that a standard 525-line television raster which contains $n_r = 490$ active line traces is just resolved in the optical projection of the 35mm print. Even with a kinescope having 3000-line resolution and an aperture response $r_{\psi(2n_r)} = 0.62$ which causes a pronounced line structure on the kinescope screen, the response in the optical 35mm projection is only 1% at $N = 2n_r$.† The carrier "ripple" has then an amplitude of 2% and a peak-to-peak amplitude of 4%.

† Failure to interlace perfectly will introduce carrier components at one-half the line number, for which the overall response is 22%.

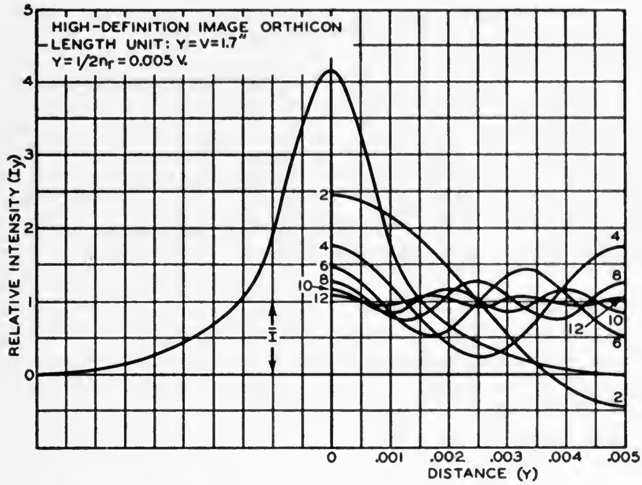


Fig. 68. Synthesis of line cross section formed by a camera-tube scanning beam for the condition $\delta \leqq 1/n_r$ (nonoverlapping).

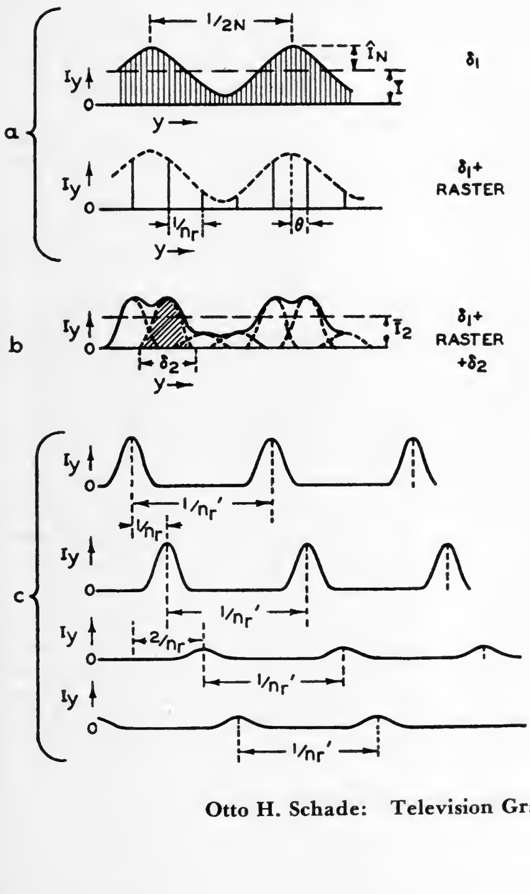


Fig. 69. Sampling and reproduction of sine-wave test pattern in the *y*-coordinate by a raster process and development of raster equation by regarding "modulated" carrier wave as the sum of interlaced carrier waves with different amplitudes.

3. Response to Sine-Wave Test Patterns and Equivalent Passband

A line raster has no effect on the sine-wave response of the apertures δ_1, and δ_2 in the x-coordinate (parallel to the raster lines), in which the aperture process is continuous. The discrete aperture positions in the y-coordinate affect the response of the two apertures in a different manner.

The analyzing aperture δ_1 "samples" the flux of a test pattern in the y-direction at the raster points only, all other aperture positions are "blocked" by the raster. What is left of the normally continuous aperture signal is a series of exact samples of its response at regularly spaced distances $\Delta y = 1/n_r$ as indicated by Fig. 69a. The reader may visualize the raster as an opaque plate with very fine slits (holes for a point raster) through which he, or a photoelectric device, views the test pattern from a fixed distance. He can control δ_1 by varying the spacing between the raster plate and the test object. When the test pattern line number N is varied, the sample amplitudes vary in direct proportion to the normal sine-wave response of δ_1. A further interpretation of these amplitudes cannot be given without considering the synthesizing aperture process.

For a linear system, the intensity of the light flux from the synthesizing aperture δ_2 is proportional to the signal amplitude delivered by δ_1 at corresponding raster points. The reproduced waveform, however, is only an artificial approximation of the test pattern wave, determined by the raster constant and the geometry of the aperture δ_2 as illustrated in Fig. 69b. The fundamental sine-wave response and the waveform distortion can be evaluated by a Fourier analysis. For this purpose the periodic wave may be regarded as the sum of a series of interlaced carrier waves, each having a constant amplitude and a wavelength $1/n_r'$ which is longer than the normal raster period (see Fig. 69c). These component carrier waves are displaced in phase by distances $1/n_r$, $2/n_r$ etc., with respect to one another and can be expressed by Fourier series (Eq. (54)) differing only in amplitude and phase of the terms. A vectorial addition of corresponding terms yields an expression for the waveform. For the conditions that the average intensity $\bar{I}_2$ in the image of the test pattern has the same numerical value as the test pattern intensity $\bar{I}$, and the transfer ratio of signals (gamma) is unity, the expression obtained for the intensity $I_{(y)^2} = f(y)$ is the following Eq. (57):

$$I_{(y)2} = \bar{I}[1 + \sum_p 2r\bar{\psi}_{(pn_r)} \cos p\pi y n_r] \quad \text{(C)}$$

$$+ \hat{I}_N r\bar{\psi}_1 r\bar{\psi}_2 \cos [(N/n_r)\pi y n_r + \theta] \quad \text{(N)}$$

$$+ \hat{I}_N r\bar{\psi}_1 \sum_p r\bar{\psi}_{(pn_r+N)} \cos [(p + N/n_r)\pi y n_r + \theta] \quad \text{(S)}$$

$$+ \imath_N r\bar{\psi}_1 \sum_p r\bar{\psi}_{(pn_r-N)} \cos [(p - N/n_r)\pi y n_r - \theta] \quad \text{(D)}$$

where

- p = 2, 4, 6, . . .
- n_r = Raster constant (number of sampling positions per length unit)
- y = Distance along y-coordinate (same length units as $1/n_r$)
- $\bar{I}$ = Average intensity in y-coordinate
- $\hat{I}_N$ = Crest intensity of sine-wave flux in test pattern
- $r\bar{\psi}_1$ = Response factor of aperture δ_1 at the line number N
- $r\bar{\psi}_2$ = Response factor of aperture δ_2 at the line number N
- $r\bar{\psi}_{(\text{index})}$ = Response factor of aperture δ_2 at line number indicated by index
- θ = Phase displacement between sample amplitude and crest $\hat{I}_N$ (Fig. 69).

The terms of Eq. (57) have been arranged in four products. The first product (C) contains only the *steady carrier components* as expressed by Eq. (54). The magnitude and numbers of the sine-wave terms depend on the aperture response of δ_2 only. The second product (N) is identified as the *normal sine-wave signal flux* $\bar{\psi}_{12}$ of the cascaded aperture δ_1 and δ_2 at the line number N. The third and fourth products (S) and (D) are harmonic components with line numbers which are the *sums and differences* of the

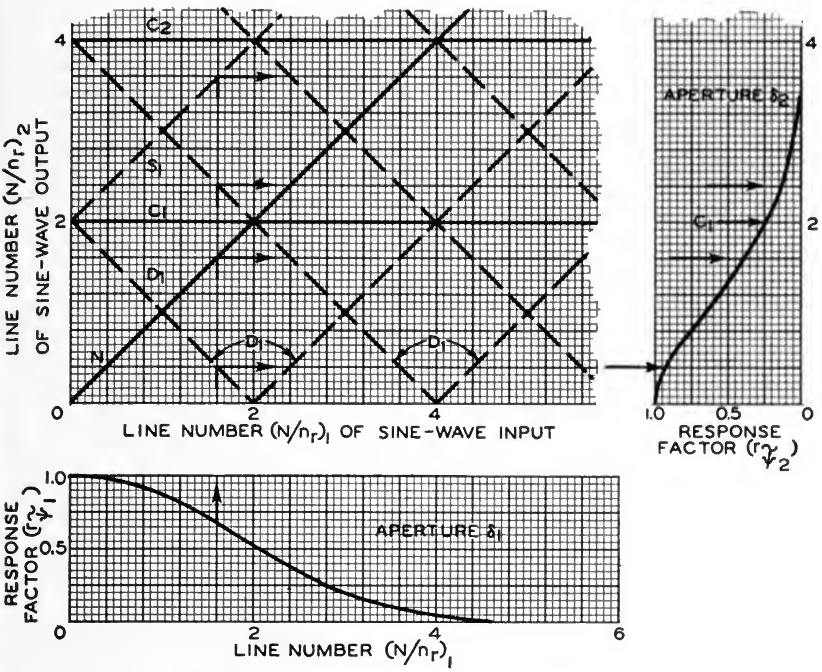


Fig. 70. Conversion characteristic of raster (Eq. (57)).

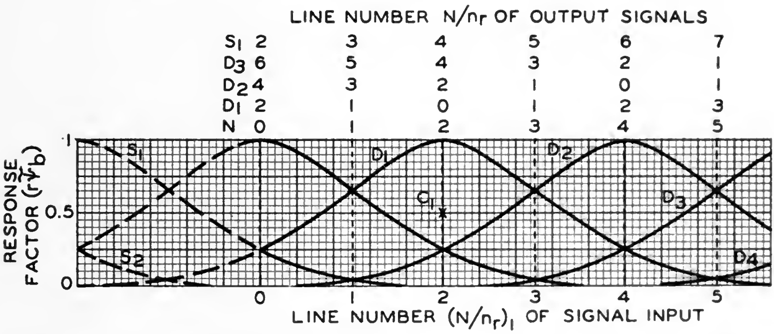


Fig. 71. Graphic representation of the combined sine-wave response of raster and synthesizing aperture δ_2 by normal aperture characteristic and "sidebands."

carrier components $2n_r$, $4n_r$ etc., and the "modulating" sine-wave signal N. Their magnitude and number depend on the response of both apertures δ_1 and δ_2.

The raster process introduces additional sine-wave components depending on the sine-wave response of the apertures δ_1 and δ_2. *The sine-wave response characteristic of the raster* itself can be represented graphically by a conversion characteristic (Fig. 70) with constant response factors $r_r = 1$ for all variable

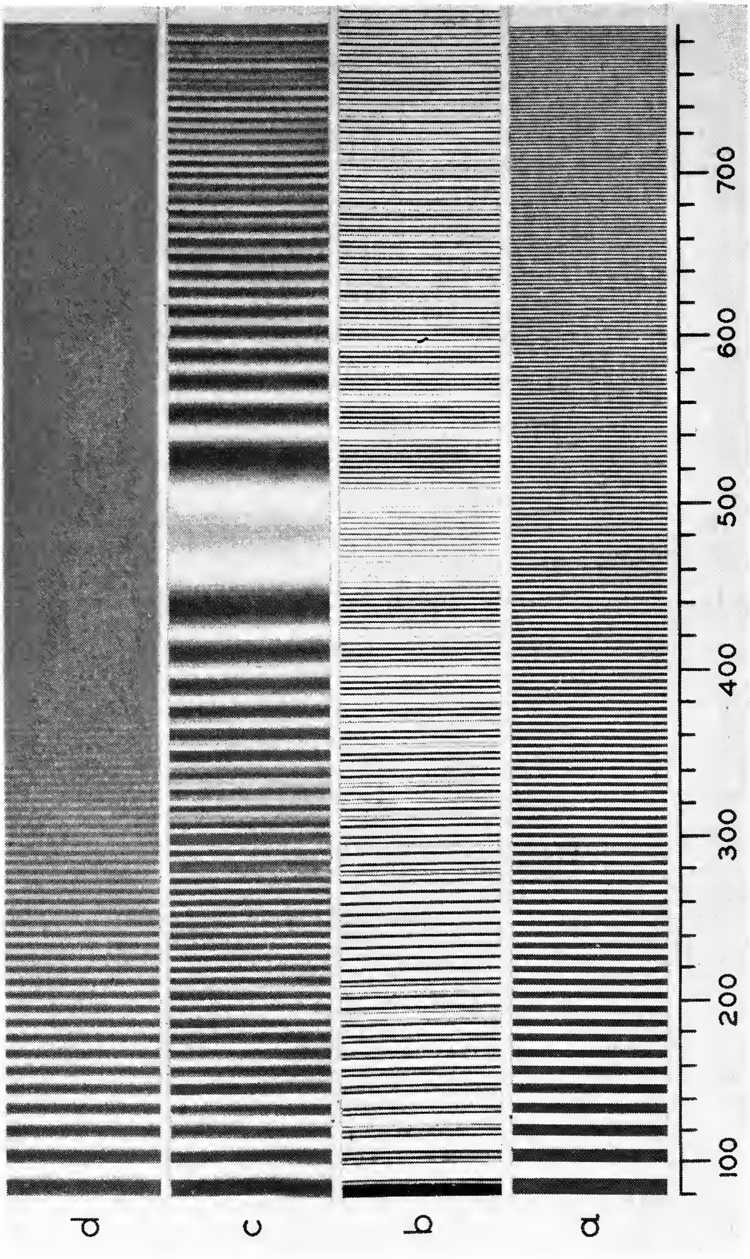


Fig. 72. Photographic proof of repeating line-number spectra ("side-bands") obtained by a line-raster process (see text).

Table XV. Sine-Wave Components $(N/n_r)_2$ and Response Factors $(r\psi)$ for $(N/n_r)_1 = 1.6$.

Component:	D_1	N	C_1	D_2	S_1	C_2
Line Number $(N/n_r)_2$	0.4	1.6	2	2.4	3.6	4
Response Factor $r\psi_1$	0.675	0.675	0.675	0.675	0.675	0.675
Response Factor $r\psi_2$	0.92	0.39	2 × 0.25	0.14	0.0	0.0
Overall Response Factor $r\psi_y$	0.62	0.263	0.338	0.945	0.0	0.0

terms and the response $r_r = 2$ for the constant carrier components. The carrier components are represented by an infinite number of horizontal lines C_1, C_2 etc., because their existence is independent of the sine-wave signal input. The line number of the normal sine-wave components (line N) and the sum and difference terms (lines S_1, S_2, S_3.... and D_1, D_2, D_3....), however, vary with the line number $(N/n_r)_1$ of the input-signal as shown by the network of diagonal raster characteristics. *The raster characteristic (Fig. 70) is a graphic representation of Eq. (57).* The use of the diagram is simple. A vertical projection of the input line number $(N/n_r)_1$ locates the output signal components at the intersections with the raster characteristics as illustrated for $(N/n_r)_1 = 1.6$. *The relative intensity of the sine-wave components* is the product of the aperture response factor $r\psi_1$, at the line number of the input-signal and the response factor $r\psi_2$ at the line number of the output-signal component. The sine-wave response characteristic of the "analyzing" aperture δ_1 is, therefore, drawn in Fig. 70 under the input coordinate of the raster characteristic, and the sine-wave response characteristic of the "synthesizing" aperture δ_2 is drawn with its line-number scale parallel to the output coordinate (both line-number scales must be in relative units N/n_r). The sine-wave response factors of the example are listed in Table XV for $(N/n_r)_1 = 1.6$.

To evaluate the total sine-wave spectrum of a raster process it is expedient to combine the raster response r_r with the response characteristic $r\psi_b = r\psi_2 r\psi_3 \ldots r\psi_n$ of succeeding apertures into one characteristic. The characteristic Fig. 71 represents the overall sine-wave response $r\psi_{rb}$ for constant amplitude sine-wave signals of the raster and a particular aperture process (δ_b) following the raster. Appropriate scales permit a direct reading of the line number and response factor $r\psi_b$ of all associated terms in the y-coordinate of the final image. The response factor $(2r\psi)$ of the single constant carrier term C_1 is indicated. The normal response characteristic (N) of the aperture δ_b appears symmetrically repeated† at each carrier line number $2n_r$, $4n_r$ etc. The response pattern between $N/n_r = 0$ and 1 repeats indefinitely. A large aperture for example has zero response at $N/n_r < 1$; its response nevertheless repeats up to infinity, periodically going to zero.

The fact that the passband of an aperture δ_b is repeated by addition of a raster process, is demonstrated by Figs. 72a to 72d. Figure 72a is a photograph of a test pattern having a variable line number.[2] A sharp photograph (δ_b small) of the pattern through a raster plate having very fine lines (δ_a small) is shown in Fig. 72b. A photograph made with a larger aperture δ_b giving a flat field is shown in Fig. 72c which may be compared with the image Fig. 72d made without raster and the same aperture δ_b. In all practical cases the infinitely repetitive spectrum of the response $r\psi_{rb}$ is limited by the finite response $r\psi_a$ of apertures *preceding* the raster, because the overall

† Electrically known as "sidebands."

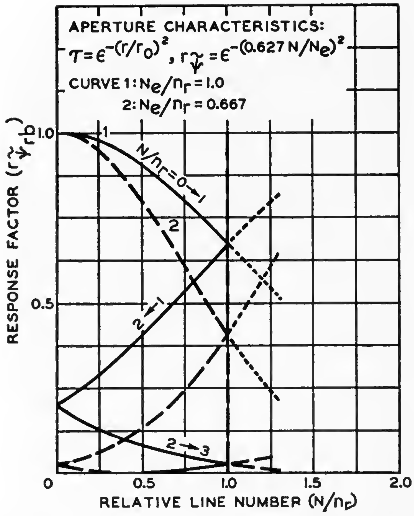


Fig. 73. Construction of repetitive spectrum by "folding" of response characteristic.

response of the entire imaging system $r\psi_{(y)} = r\psi_a r\psi_b r_r$ becomes zero when the response factor $r\psi_a$ is zero.

4. Sine-Wave Spectrum and Equivalent Passband $N_{e(s)y}$ for Random Deviations

For the analysis of deviations it is unnecessary to examine the waveform and phase distortion caused by the raster (to be discussed in Part IV of this paper), because the distribution of sine-wave components in a source of deviations is random. The sine-wave spectrum for deviations is, hence, obtained by arranging all sine-wave components in order of their line number, combining response factors at equal line numbers by a quadrature addition (square root of the sum of the squares). This process has been carried out for a variety of aperture combinations δ_a and δ_b having exponential cross sections $\tau = \epsilon^{-(r/r_0)^2}$ and a sine-wave response $r\psi = \epsilon^{-(0.627N/N_e)^2}$ (Fig. 44, Part II) which is a satisfactory equivalent for optical processes. The repetitive section of raster and aperture response characteristic $r\psi_{rb}$ can be constructed by "folding" the normal response characteristic into the range $N/n_r = 0$ to 1 as illustrated in Fig. 73 for two aperture sizes $N_e/n_r = 1$ and $N_e/n_r = 0.667$.

Overall sine-wave spectra computed for various combinations of aperture sizes are shown in Figs. 74a to 74c. When both apertures δ_a and δ_b are large, i.e., when N_e is smaller than the raster constant ($N_e/n_r = 0.5$ in Fig. 74a), the sine-wave spectrum is substantially the same as without raster; when $N_{e(b)}$ is increased, the high-"frequency" components increase considerably faster than without raster and show periodic maxima and minima. These variations decrease when $N_{e(a)}$ is increased (Fig. 74b), and disappear substantially for values $N_{e(a)} = 1$ (Fig. 74c). It is concluded that the addition of a raster process may increase the normal sine-wave response and extend the aperture passband to higher line numbers even for the "flat-field" condition $N_{e(a)} = N_{e(b)} = 0.67\, n_r$ (Fig. 74b). The raster can, therefore, have a substantial *negative aperture effect* which increases the intensity and edge sharpness of the reproduced grain structure in the *y*-coordinate.

The equivalent passband $N_{e(s)v}$ of the raster process is the integral of squared response factors (Eq. (28), Part II) determined from the total sine-wave response of the system. The computation of the integral for various aperture combinations can be simplified by calculating the *rms response* of δ_b for the repetitive section $N/n_r = 0$ to 1. The rms response factor $[r\psi]_b$ at each input line number (Fig. 75) is obtained by a quadrature addition of associated sine-wave components (shown in Fig. 73). Because this response is repetitive, the integral

$$N_e = \int_0^\infty ([r\bar{\psi}]_b r\psi_a)^2_{N/n_r} d(N/n_r)$$

can be evaluated within the limits $N/n_r = 0$ and 1 from

$$N_{e(s)v} = \int_0^{N/n_r=1} ([r\psi]_b [r\psi]_a)^2_{(N/n_r)} d(N/n_r) \qquad (58)$$

where $[r\psi]_a$ is the rms value of response factors of δ_a, coordinated by folding the

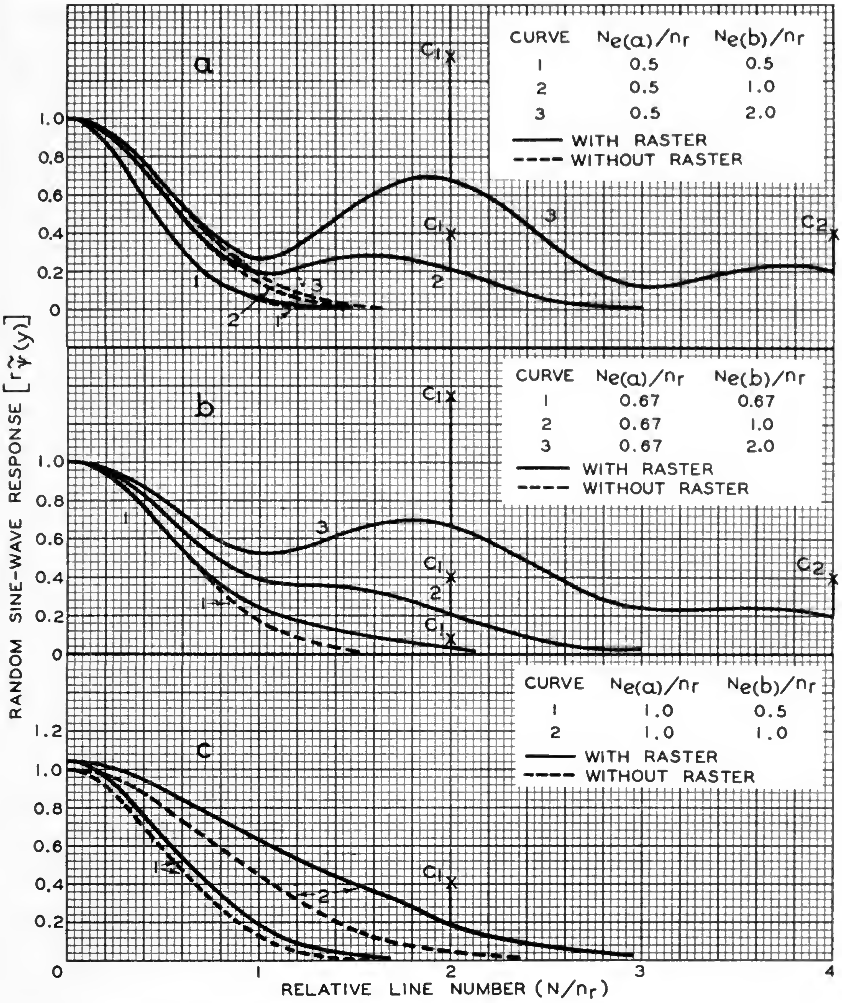


Fig. 74. Overall sine-wave spectra of raster processes for various aperture sizes δ_a and δ_b.

response characteristic $r\tilde{\psi}_a$ into the limits $N/n_r = 0$ to 1. The values $[r\tilde{\psi}]_a$ and $[r\tilde{\psi}]_b$ are identical when $\delta_a = \delta_b$. The products of various aperture combinations are, thus, easily computed from Fig. 75. The equivalent passbands $N_{e(s)v}$ of the system are plotted in Fig. 76 as a function of the passband $N_{e(a)}/n_r$ of the analyzing aperture δ_a with $N_{e(b)}/n_r$ as a parameter. Examination of these functions reveals the following facts.

(*a*) *When both $N_{e(a)}$ and $N_{e(b)}$ are smaller than $0.7n_r$* the aperture flux at successive raster points is correlated sufficiently (overlapping) to eliminate the effect of the raster. The equivalent passband

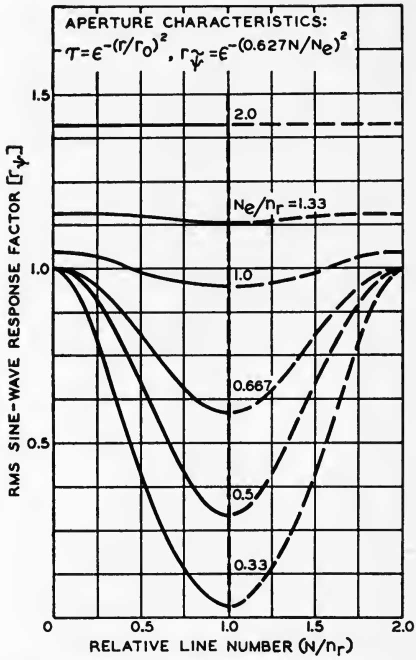


Fig. 75. Rms response of apertures and raster to sine-wave signals.

$N_{e(s)v}$ of the process can then be computed from the normal aperture response without raster or may be approximated with good accuracy by the cascade formula:

$$1/N_{e(s)v} = (1/N_{e(a)}^2 + 1/N_{e(b)}^2)^{\frac{1}{2}} \quad (59)$$

(*b*) *When one or both values $N_{e(a)}$ or $N_{e(b)}$ are greater than n_r*, the aperture flux is no longer correlated by at least one aperture, and the equivalent passband of the process can be computed with good accuracy from the product.

$$N_{e(s)v} \simeq (N_{e(a)}N_{e(b)})/n_r \quad (60)$$

(*c*) *For all other values* the aperture flux is partially correlated and the value $N_{e(s)v}$ should be computed as outlined above or may be approximated by the values computed for exponential aperture characteristics (Fig. 76). It should be mentioned that a square aperture presents a special case because of its strongly periodic aperture response and large number of terms which cause periodic deviations from the characteristics shown in Fig. 76. The square aperture is of interest as a mathematical equivalent, but its characteristics are in many cases undesirable for practical processes. The greatly enlarged reproduction of a photographic grain structure by point- and line-raster processes is illustrated in Fig. 77. The original grain structure is shown in Fig. 77a. The samples "seen" through a fine point raster plate (δ_a small) are shown in Fig. 77b; their reproduction by a square aperture providing a "flat" field is shown in Fig. 77c. Reproduction of the same grain structure by a line-raster process using a square reproducing aperture is shown in Figs. 77d and e. The higher horizontal definition obtained with a vertical slit aperture is illustrated by Fig. 77f.

A comparison of a line-raster process (a) using a round $\cos^2$ aperture δ_b with a continuous process (b) using the same apertures is shown with a lower magnification in Fig. 78. The slight increase in vertical sharpness by the raster process (a) observed in the originals will probably be lost in the printing process.

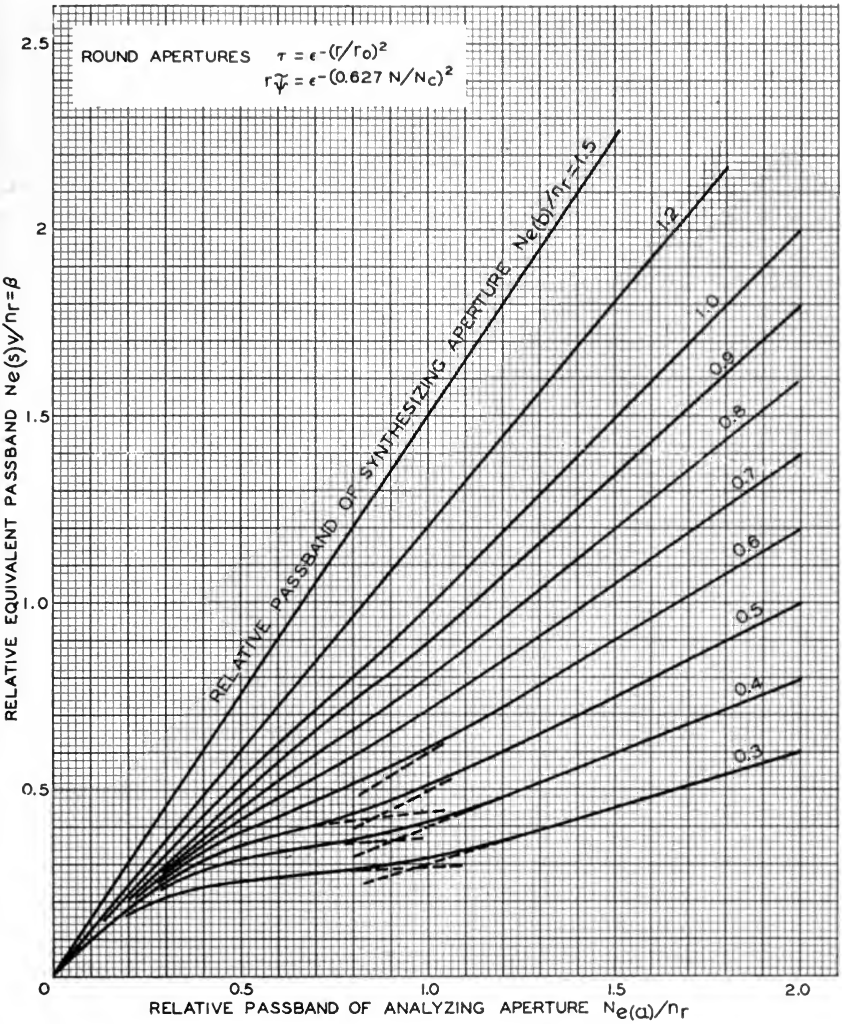


Fig. 76. Equivalent relative passband (β) of systems containing a raster process as a function of the relative passband $N_{e(a)}/n_r$ of the analyzing aperture δ_a for various relative passbands $N_{e(b)}/n_r$ of the synthesizing aperture δ_b.

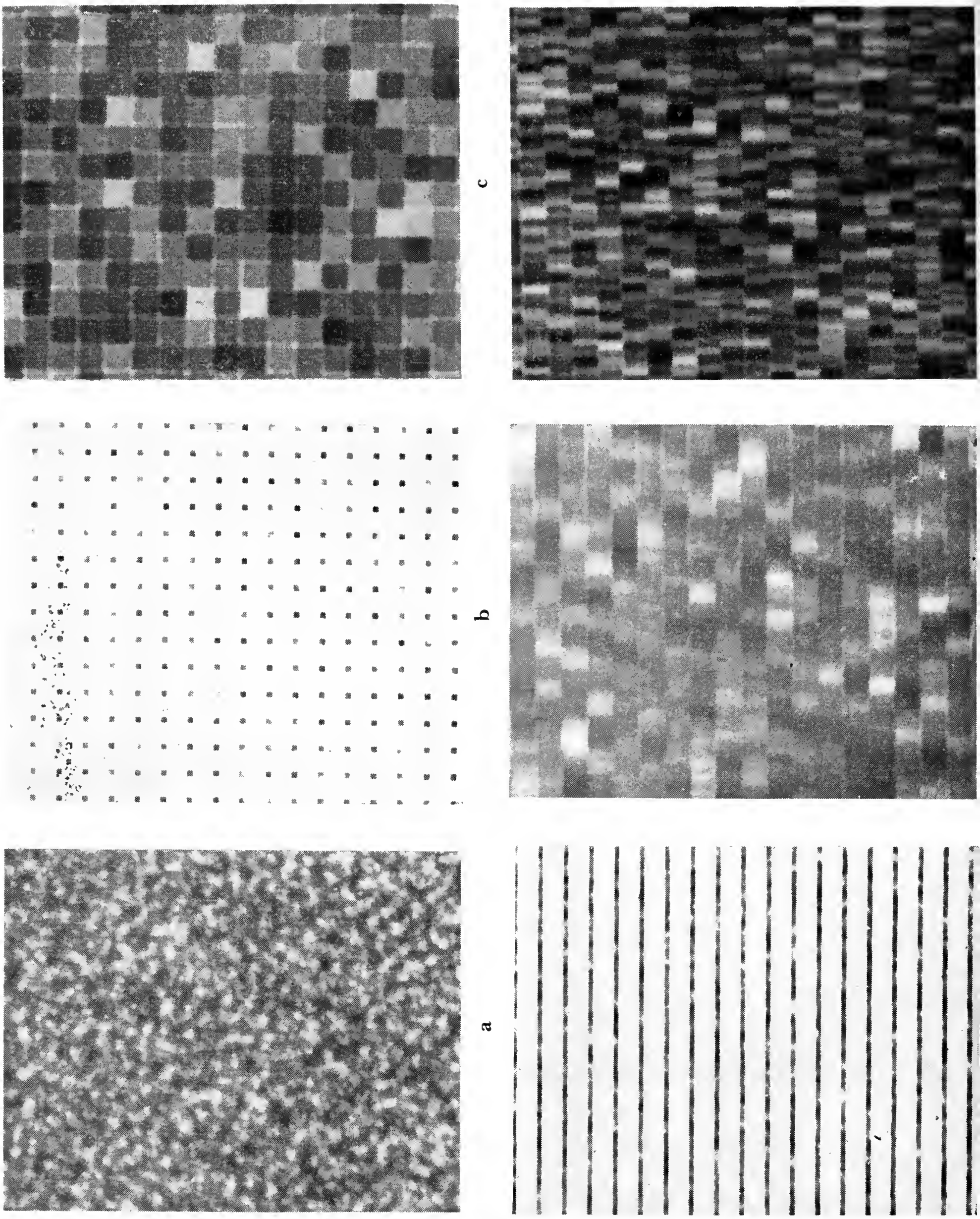


Fig. 77. Reproduction of photographic grain structure by point- and line-raster processes with rectangular apertures (highly magnified).

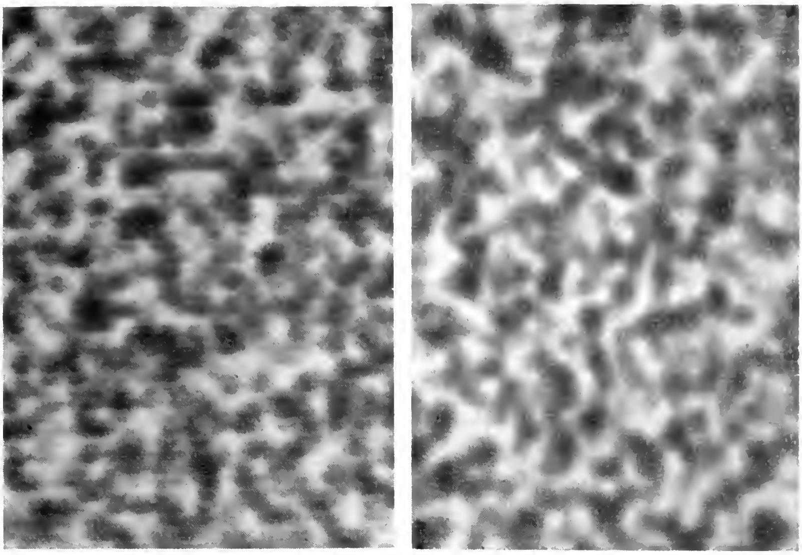


Fig. 78. Grain structure reproduced (a, at left) with, and (b, at right) without line-raster process by a round $\cos^2$ aperture.

NOTE: Figures 85 and 109 now follow on this coated paper insert. Figures 79, etc., are arranged below as best possible for nearness to pertinent text.

C. ELECTRICAL CONSTANTS AND APERTURES OF TELEVISION SYSTEMS

1. Frequency and Line Number

The transmission of two-dimensional images over an electrical frequency channel is based on a conversion of lengths into units of time. To effect this conversion, television systems make use of a horizontal-line raster scanned by a single aperture. The signals of all aperture positions in the raster are transmitted in sequence because of a time-proportional displacement of the aperture along the raster lines. The correlation of length and time units depend obviously on the dimensions of the raster, the order in which the raster lines are scanned, and the time T_f assigned for the transmission of one picture frame. The principal relations are illustrated in Fig. 79 for a raster constant $n_r = 12$ and the normal frame aspect ratio $H/V = 4/3$. A time allowance must be made for synchronizing signals and the finite return periods of the scanning apertures. These time percentages are the "blanking" periods t_{b_v} and t_{b_h} in Figs. 79b and c which correspond to the blanking margins b_h and b_v in Fig. 79a.

The length unit l is the vertical frame dimension V, as indicated in Fig. 79a. In the vertical coordinate the length l or any subdivision down to $\Delta l = 1/N_v = 1/n_r$ corresponds to relatively long time intervals, i.e., low electrical frequencies.

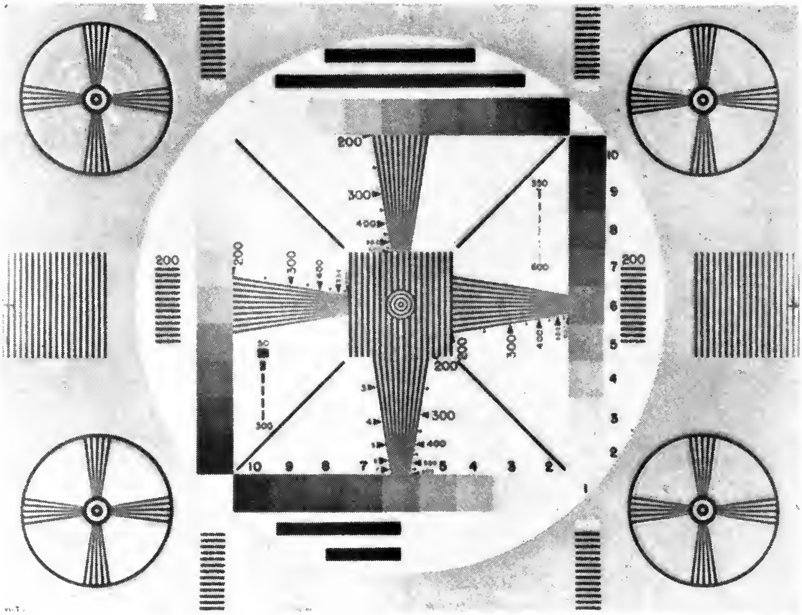


Fig. 85a. Composite print made by a photographic synthesis (Fig. 84).

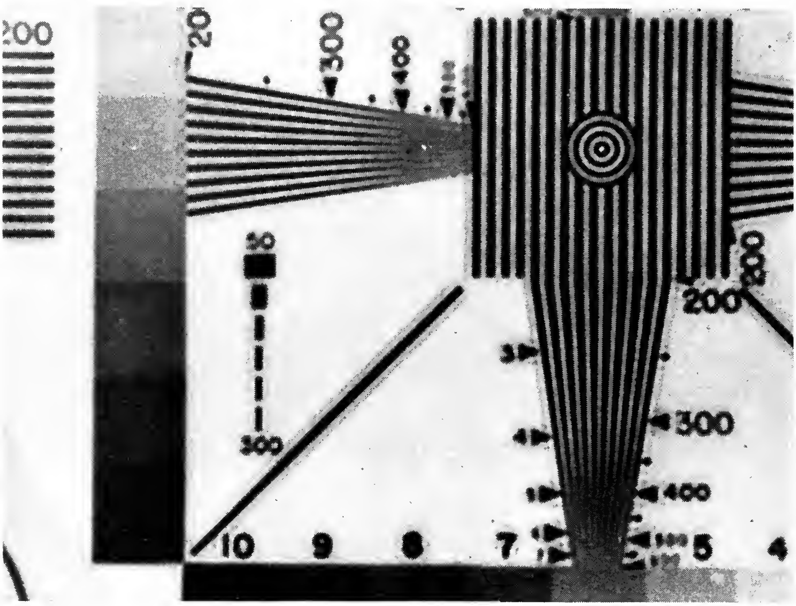


Fig. 85b. Enlarged section of Fig. 85a showing edge "transients" in two coordinates.

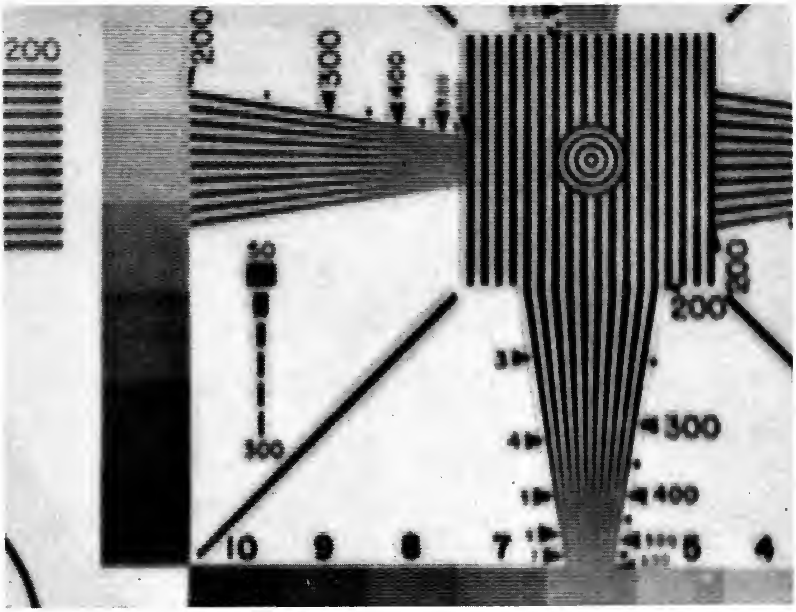


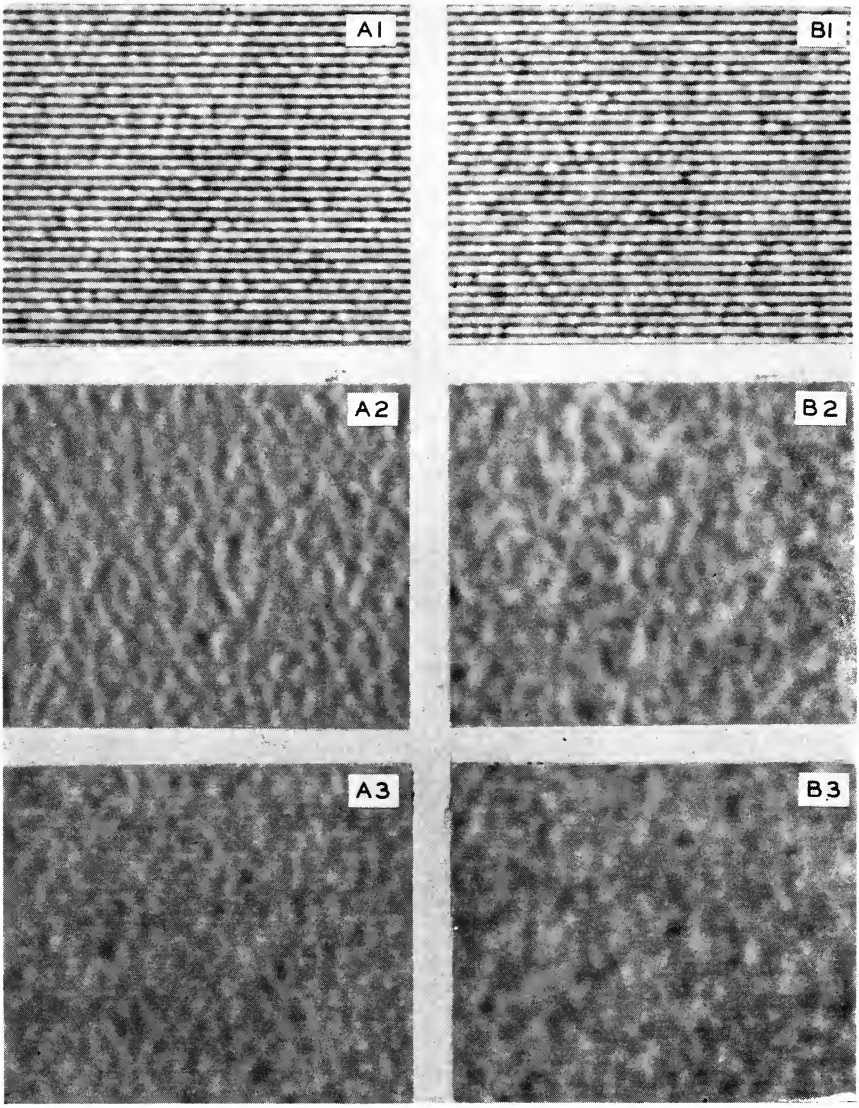
Fig. 85c. Addition of optical line-raster process to Fig. 85b.

A test pattern with $N_v = 2$ (right side of Fig. 79a) filling the entire frame area generates the video signal illustrated in Fig. 79b. The electrical frequencies f_v required for the reproduction of vertical sine-wave samples N_v are determined by the raster constant n_r. The highest electrical frequency $f_{v\,\max}$ is generated when the signal amplitudes in *successively traced*† raster lines alternate between two values. One period is, therefore, completed in the time $2t_h = 2T_f/n_s$ (see Fig. 79b).

In all properly operating television systems the electrical sine-wave response is unity and is without phase error from the frame frequency $(1/T_f)$ on upwards to far beyond the frequencies occurring in the reproduction of vertical sine-wave samples. The sine-wave response, therefore, does not enter as a factor limiting the vertical sine-wave response of the television system. *The vertical response of the television system* is determined entirely by the raster constant n_r and the two-dimensional system apertures as described in the preceding section.

In the horizontal coordinate the length unit $l = V = 3/4H$ (see Fig. 79c) and the length of half-waves l/N_h in a sine-wave test pattern are scanned in very short time intervals t_{N_h} corresponding to high electrical frequencies. The spatial frequency of the optical test pattern wave has the value $0.5N_h/l$. The horizontal time unit is three fourths of the active line time, and the electrical frequency corresponding to a line number N_h is therefore:

† It is noted that successively traced raster lines in a 2 to 1 interlaced raster are either the even or the odd numbered raster lines which correspond to a test pattern line number $n_r/2$. Without interlacing, the frequency f_v max has the same value but the test pattern line number producing it is equal to n_r. With 2 to 1 interlace, a line number equal to n_r causes constant amplitude signals in one complete field and constant signals of different amplitude in the following field.



$$f_h = 0.5c\ N_h n_r / T_f \text{ cycles/sec} \quad (61)$$

where

T_f = Frame time in seconds ($\frac{1}{30}$ sec in standard television system)

n_r = Number of active raster lines in frame area

N_h = Horizontal line number

c = $(H/V)/(1 - b_h)(1 - b_v)$; the standard value is $c = (4/3)/(0.84 \times 0.935) = 1.7$

The total number of scanning lines including the inactive lines in the blanking margin b_v is usually stated as the scanning line number of the system, which is

$$n_s = n_r/(1 - b_v) = 1.07\ n_r \quad (62)$$

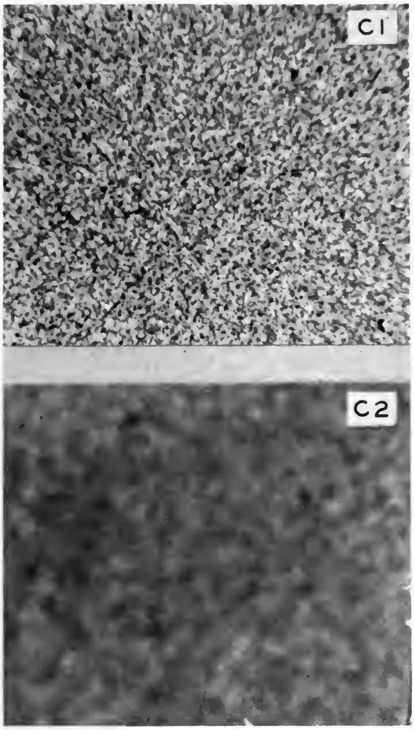


Fig. 109, A1–3 and B1–3 at left, and C1 and C2 above. Grain structures of television and motion-picture processes.

2. Theoretical Passband and Aperture (δ_f) of Television Systems

The video frequency channel of the television system is determined by the frame time T_f, the raster constant n_r, and the desired horizontal cutoff resolution $N_{c(h)}$ of the system; it is given for normal blanking percentages by the relation

$$\Delta f = 0.85\ N_{c(h)}n_r/T_f \text{ cycles/sec} \quad (63)$$

The product $(N_{c(h)}n_r)$ corresponds to the square of the equivalent passband $\bar{N}_e^2 = (N_{e(h)}N_{e(v)})$ of an optical aperture. The relation between the theoretical passband Δf of a television channel and its optical equivalent $\bar{N}_{e(f)}$ is, therefore:

$$\bar{N}_{e(f)} = (N_{c(h)}n_r)^{\frac{1}{2}} = K(\Delta f)^{\frac{1}{2}} \quad (64)$$

For normal blanking percentages the proportionality factor has the value $K = (T_f/0.85)^{\frac{1}{2}}$. The product $(N_{c(h)}n_r)$ has the dimension (length)$^{-2}$, and its reciprocal represents a rectangular area of uniform transmittance which may be regarded as an *equivalent point image or sampling aperture of a theoretical television channel.* This equivalent sampling aperture is often referred to as a "picture-element." The term is misleading because the concept of an element implies an invariable intensity distribution in a small area of fixed size. A process which is continuous in one coordinate forms an infinite number of point images and its true "elemental" area is infinitesimal. Only a point raster process can produce an elemental area of finite size.

The concepts of a *two-dimensional aperture δ_f having the exact response characteristic of a theoretical television channel* is useful for an interpretation of electrical random fluctuations (noise) in terms of optical deviations.

Electrical signal-to-noise ratios are usually computed for a given passband Δf having a theoretically sharp cutoff. This evaluation is analogous to the process of sampling a two-dimensional grain structure with a measuring aperture $\delta_m = \delta_f$ of known geometry to determine a reference value $[R]_m$ for the particular random structure (see Part II D). The sources of electrical random fluctuations in a television system (see Fig. 65) can, therefore, be replaced by random particle structures scanned by a hypothetical television camera. The scanning aperture of this camera is infinitesimal and

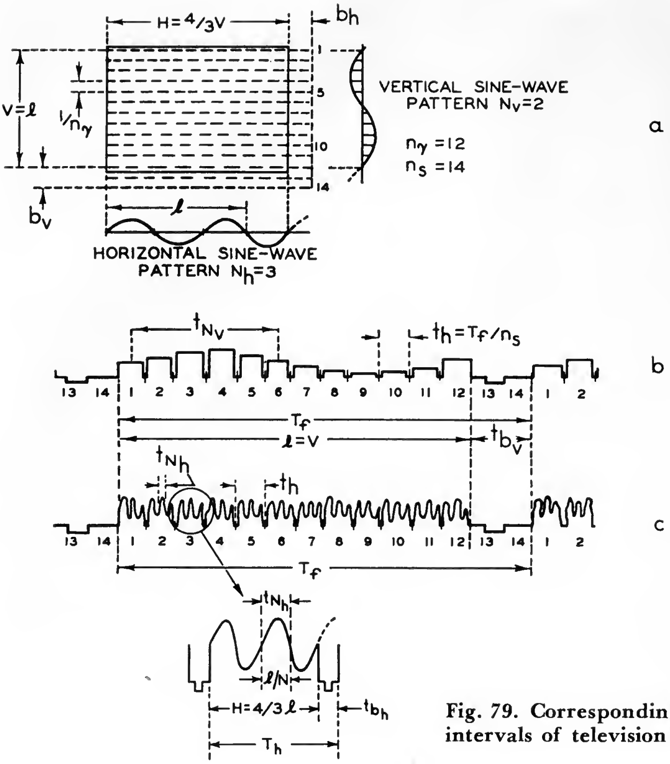


Fig. 79. Corresponding lengths and time intervals of television frame and signals.

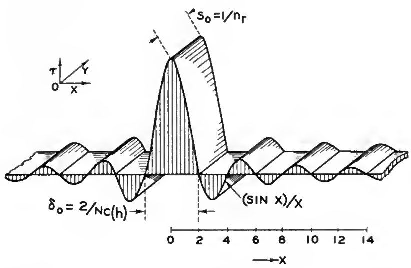


Fig. 80. Equivalent point image or sampling aperture of theoretical television channel.

its output signals are modified by the equivalent passband $\bar{N}_{e(s)}$ of the system elements following the "noise" source. The granularity (noise level) of the structure is computed by assuming that it is scanned with a measuring aperture $\delta_m = \delta_f$ which must fill the requirements that its signals are indistinguishable from electrical fluctuations in the corresponding theoretical channel Δf. The horizontal sine-wave response of δ_f is, therefore, constant in the passband $N_{e(h)} = N_{c(h)}$, its equivalent vertical passband is $N_{e(v)} = n_r$, and the aperture signals in different raster lines are uncorrelated.

The frequency spectrum of δ_f in the vertical coordinate may be determined as follows: it is assumed for simplicity that no interlacing is used. A vertical cross section in the frame area corresponds to a series of amplitude samples taken from the electrical aperture signal at the line intervals t_h (see Fig. 79). The sampling of constant electrical sine-wave signals by the raster process results in a series of constant sample amplitudes ($N_v = 0$) for all frequencies which are integral multiples of the line frequency $f_h = 1/t_h$. When the signal frequency is changed by an increment $\Delta' f = f_h/2$, the sample amplitudes alternate between two fixed values at a frequency corresponding to the line number $N_v = n_r$. Frequency increments $\Delta' f$ between $\Delta' f = 0$ and $\Delta' f = f_h/2$ as well as between $\Delta' f = f_h$ and $\Delta' f = f_h/2$ cause a sequence of sample amplitudes identical with those obtained with an aperture sampling optical sine-wave patterns with line numbers from $N_v = 0$ to $N_v = n_r$. The amplitudes of the electrically taken samples vary according to the phase relation between sampling points and sine-wave signal, just as aperture samples depend in magnitude on the relative phase between the raster lines and the optical sine-wave pattern. The electrical samples can, therefore, be attributed to a hypothetical aperture δ_f scanning sine-wave patterns with a line number range $N_v = 0$ to $N_v = n_r$. This range of line numbers is sampled repetitively throughout the video frequency band in every increment $\Delta' f = f_h/2$. Because the electrical response within any one of these small sections of the video passband is substantially constant, the rms values of the aperture signals at any one line number $N_v = 0$ to n_r from all sections $\Delta' f$ are alike. The vertical sine-wave response of δ_f is constant between $N = 0$ and $N = n_r$ and independent of the horizontal response characteristic of the video system.

The raster characteristic (Fig. 70) transforms this limited constant amplitude spectrum into an infinite frequency spectrum (see section B4) which is subsequently limited by the real aperture δ_b following the raster process, and results in an overall response identical with the response characteristic of δ_b. *An electrical "noise" source followed by a "flat" video channel Δf with theoretical rectangular cutoff can, therefore, be replaced by a random particle structure scanned by an aperture δ_f having constant sine-wave response in both x- and y-coordinates within the range of line numbers $N_{c(h)}$ and n_r respectively.* The equivalent passband of this hypothetical scanning aperture is $\bar{N}_{e(f)} = (N_{c(h)} n_r)^{\frac{1}{2}}$ as stated by Eq. (64).

It is of interest to determine the geometric characteristics of this aperture. A harmonic synthesis of the horizontal aperture cross section from its response characteristic (see Eq. 54) shows that the *transmittance* τ_h varies as a $(\sin x)/x$ function (Fig. 80) and has positive and negative portions decaying slowly to zero at infinity.† The central peak between the first zero points has a dimension $\delta_0 = 2/N_{c(h)}$. The aperture transmittance τ_v in the vertical coordinate (y) can be given a rectangular shape with constant transmittance $\tau_v = 1$ and a width $s_0 = 1/n_r$. This dimension meets the requirements $N_{e(v)} = n_r$ and that signals in different scanning lines be uncorrelated. The continuous sine-wave response (in y) of this rectangular aperture has a $(\sin x)/x$ form with a first zero at $N_v = 2n_r$. In conjunction with the raster characteristic, however, the $(\sin x)/x$ response produces a frequency spectrum identical with that from a constant aperture response in the range $N/n_r = 0$ to 1. The $(\sin x)/x$ response "folded" into this range results in unity rms response factors when the response factors of all input frequencies giving the same output frequency, are combined.

3. Horizontal Sine-Wave Response and Aperture Characteristics of Electrooptical Systems

(*a*) *General Formulation.* The principal elements determining the horizontal response characteristic of a television system are indicated in the block diagram Fig. 65. The horizontal sine-wave response of television systems can be made very dissimilar to that of optical systems by adjustment of the response

† An optical synthesis of images with apertures containing negative flux components is discussed in the following section.

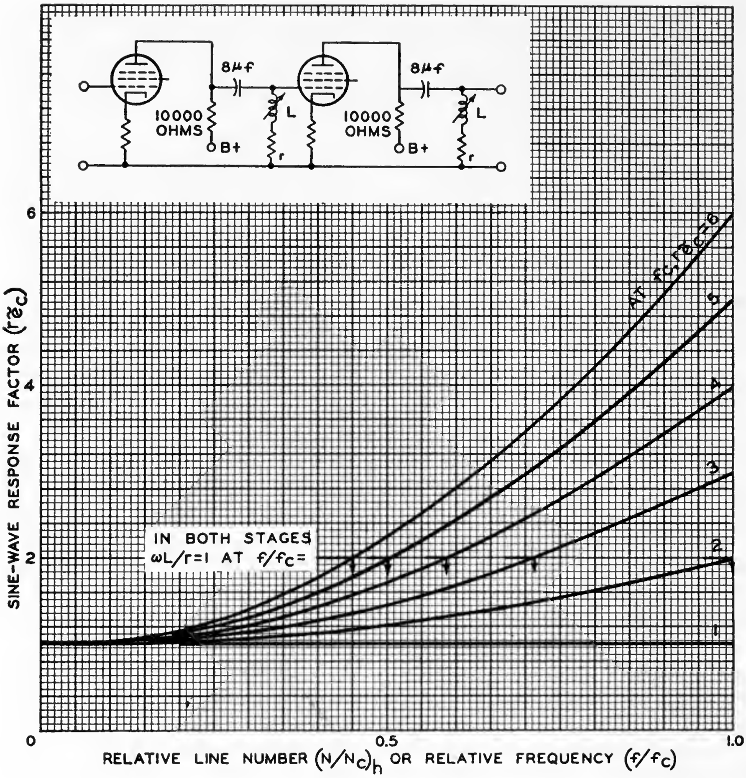


Fig. 81. Aperture correction circuit and response characteristics.

characteristic $r_{\tilde{\xi}}$ of the video system. The response of amplifiers and filter circuits is normally constant within a substantial portion of their passband but can also be given a rising characteristic by corrective networks. The sine-wave response $r_{\tilde{\xi}c}$ of a two-stage amplifier circuit for correcting the sine-wave response of camera tubes is shown in Fig. 81. A phase-correcting circuit is used in conjunction with the amplitude-correcting circuits. Electrical networks of this type are termed *aperture-correction circuits* because they can completely or partially compensate the decreasing horizontal response $r_{\tilde{\psi}h}$ of two-dimensional apertures. The horizontal response of an electrooptical system is given in general by

$$r_{\tilde{\psi}(s)h} = (r_{\tilde{\xi}} r_{\tilde{\psi}})_{(N/N_c)h} \qquad (65)$$

where

$r_{\tilde{\xi}} = (r_{\tilde{\xi}12} r_{\tilde{\xi}c} r_{\tilde{\xi}f})_{(f/f_c)}$ = overall electrical response characteristics

$r_{\tilde{\xi}12} = r_{\tilde{\xi}1} r_{\tilde{\xi}2}$ = response of preamplifier ($r_{\tilde{\xi}12} = 1$ for an equalized preamplifier, see discussion in 3(*c*)

$r_{\tilde{\xi}c}$ = response factor of aperture correction circuits (Fig. 81)

$r_{\tilde{\xi}f}$ = response factor of low-pass filter (Fig. 82)

$N_{c(h)}$ = horizontal cutoff resolution (Eq. 63))

$r_{\tilde{\psi}} = (r_{\tilde{\psi}(a)} r_{\tilde{\psi}(b)})_{(N/N_c)h}$ = response characteristic of all two-dimensional system apertures.

(*b*) *Apertures and Aperture Effects of Electrical Elements.* An aperture correction $r_{\tilde{\xi}c} = 1/r_{\tilde{\psi}}$ results in a system response equal to that of the cutoff filter:

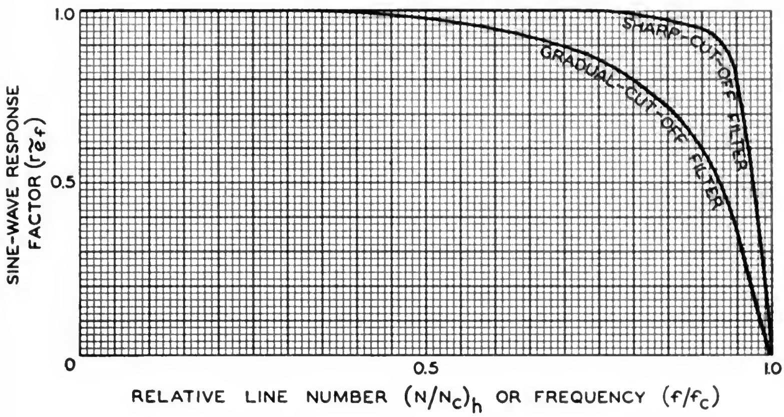


Fig. 82. Sine-wave response of electrical low-pass filters.

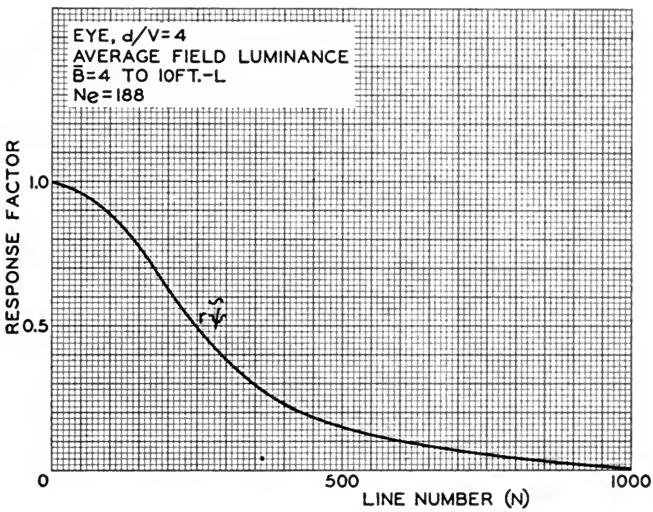


Fig. 83. Sine-wave response of the eye at moderate brightness levels and a viewing distance $d = 4V$.

$r\psi_{(s)} = r\tilde{e}_f$. The degree of aperture correction permissible in a particular case depends on the horizontal resolution $N_{c(h)}$ of the television system and the viewing distance which determines the relative aperture response of the eye. When the cascaded response characteristic $r\psi_{(s)} r\psi_{\text{eye}}$, *including the visual system*, departs markedly from that of an optical aperture (excessive high-frequency response), the corresponding retinal point-image has abnormal characteristics because it has a transmittance (τ_s) with negative portions (compare Fig. 80). Such apertures cause edge transitions distorted by "transient" overshoots or oscillations, and result in a relief effect or multiple contour lines. It is not difficult

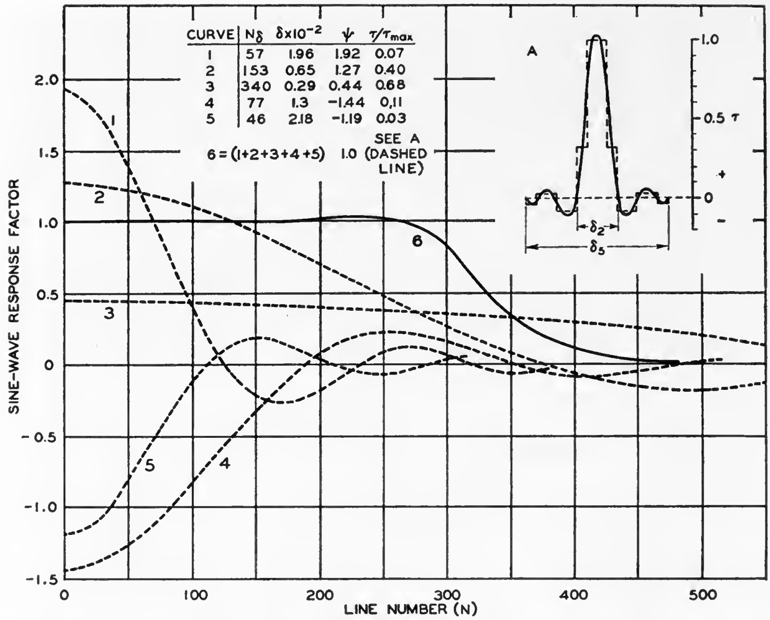


Fig. 84. Synthesis of a "flat"-response characteristic with sharp cutoff by addition of 3 positive- and 2 negative-response characteristics of round apertures with uniform transmittance.

to see that a system response $r\psi_{(s)}$ extending beyond two-thirds of the passband of the eye (see Fig. 83) can be given a constant value with sharp cutoff without causing an abnormal overall response in the retinal image. When the cutoff of the television system, however, occurs in the lower half of the visual passband, due to low system resolution or close viewing distances, aperture correction must be limited to a system response $r\psi_{(s)}$ having more gradual cutoff, to prevent abnormal optical conditions in the retinal image.†

The effects of apertures having negative transmittance can be demonstrated by a photographic correction process. The response characteristic (6) of the point image shown in Fig. 84, for example, can be synthesized by superimposition of three positive and two negative components. Images can be synthesized by two sets of out-of-focus projections with appropriate lens stops. The positive-aperture effects are combined in one plate by a triple exposure. The negative-aperture plate is made by a double exposure with positive apertures and reversed in polarity in a contact print. A composite print from the positive and negative plates in register is shown in Figs. 85a and b and illustrates the transients and sharp cutoff (in both image coordinates) produced by the response

† This subject will be discussed further in Part IV.

Figures 85a, 85b and 85c are on plate pages 116 and 117.

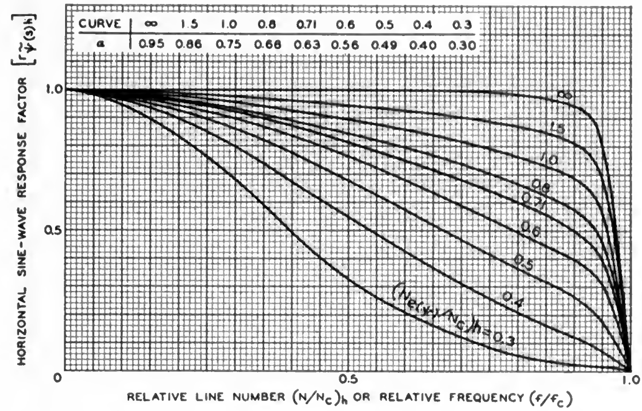


Fig. 86a. Normalized response characteristics for "flat" channel with sharp-cutoff filter (Fig. 82) in cascade with exponential apertures and 1× aperture correction (Fig. 81).

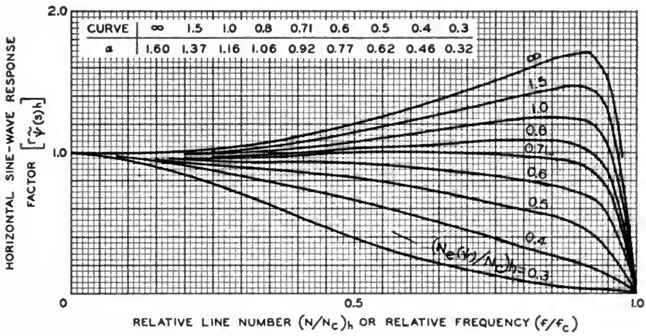


Fig. 86b. Normalized response characteristics for "flat" channel with sharp-cutoff filter (Fig. 82) in cascade with exponential apertures and 2× aperture correction (Fig. 81).

characteristics, Fig. 84. The similarity with an over-compensated television process can be increased by the addition of a raster process as shown in Fig. 85c. At increased viewing distances the undesirable transients disappear, because the overall response is then given a normal shape by the eye characteristic.

(*c*) *Generalized Response and Aperture Characteristics.* The sine-wave response characteristics of electrooptical systems have been computed in normalized units as a function of system parameters to simplify numerical evaluation. The curve families Figs. 86 and 87 are plots of Eq. (65) for an electrical response $r_{\tilde{z}}$ with four values of aperture correction and two different filter characteristics, in cascade with various optical apertures. The cascaded response of all two-dimensional apertures in the system under consideration is closely approximated by the response characteristic $r_{(\tilde{\psi})}$ of one equivalent exponential aperture (Fig. 44 and Table VII, Part II). The parameter $(N_{e(\tilde{\psi})}/N_c)_h$ specifies the equivalent pass-

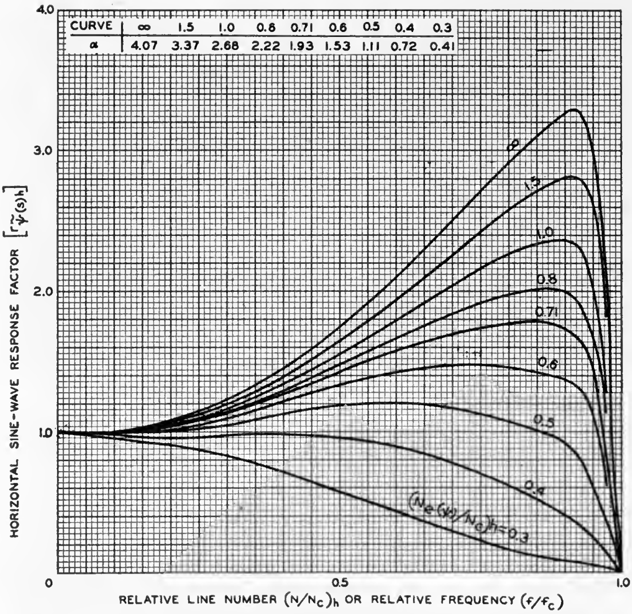


Fig. 86c. Normalized response characteristics for "flat" channel with sharp-cutoff filter (Fig. 82) in cascade with exponential apertures and 4× aperture correction (Fig. 81).

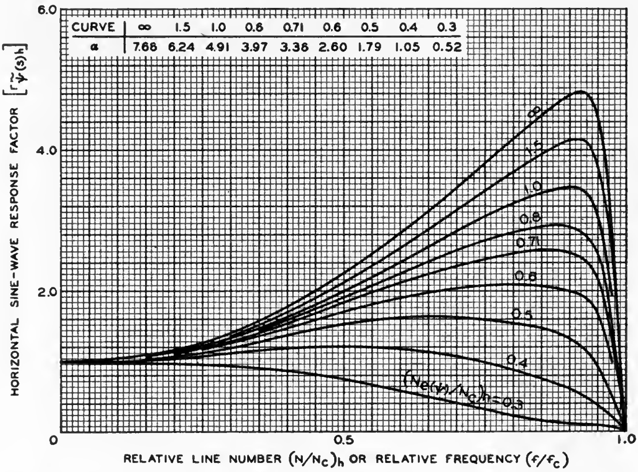


Fig. 86d. Normalized response characteristics for "flat" channel with sharp-cutoff filter (Fig. 82) in cascade with exponential apertures and 6× aperture correction (Fig. 81).

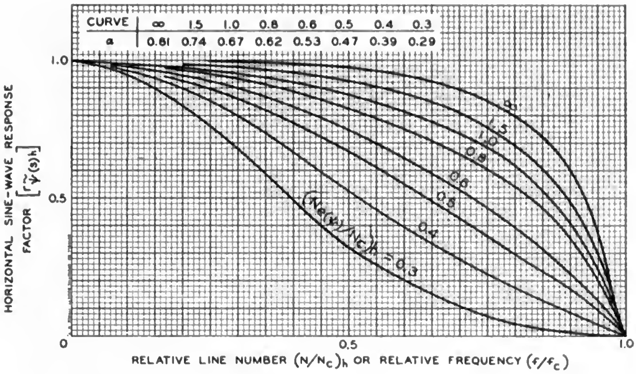


Fig. 87a. Normalized response characteristics for "flat" channel with gradual-cutoff filter (Fig. 82) in cascade with exponential apertures and 1× aperture correction (Fig. 81).

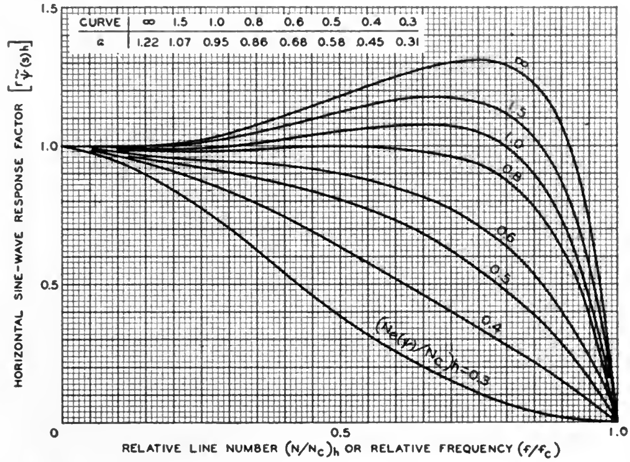


Fig. 87b. Normalized response characteristics for "flat" channel with gradual-cutoff filter (Fig. 82) in cascade with exponential apertures and 2× aperture correction (Fig. 81).

band of this aperture relative to the theoretical bandwidth $N_{c(h)}$ of the electrical system. The equivalent passband $N_{e(s)h}$ of the response characteristics is specified likewise in relative units by the ratio $\alpha = (N_{e(s)}/N_c)_h$ defined as the *bandwidth factor* in section D1.

If the system is considered as a purely electrical network, the *aperture transmittance* τ_h *of the system* is its response to a single impulse of infinitesimal duration. The optical equivalent is the response of the electrooptical system to isolated lines of infinitesimal width. The impulse shapes or aperture cross sections (transmittance τ_h) corresponding to the response characteristics Figs. 86 and 87 have been computed by a Fourier synthesis (Eq. (54)) which is valid for the condition of zero phase shift or a linear

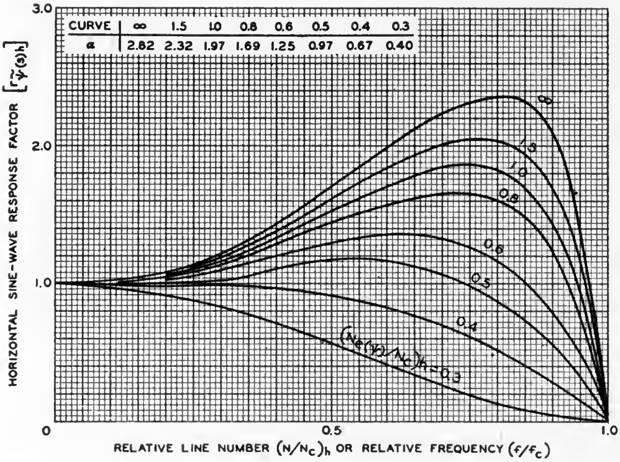


Fig. 87c. Normalized response characteristics for "flat" channel with gradual-cutoff filter (Fig. 82) in cascade with exponential apertures and 4× aperture correction (Fig. 81).

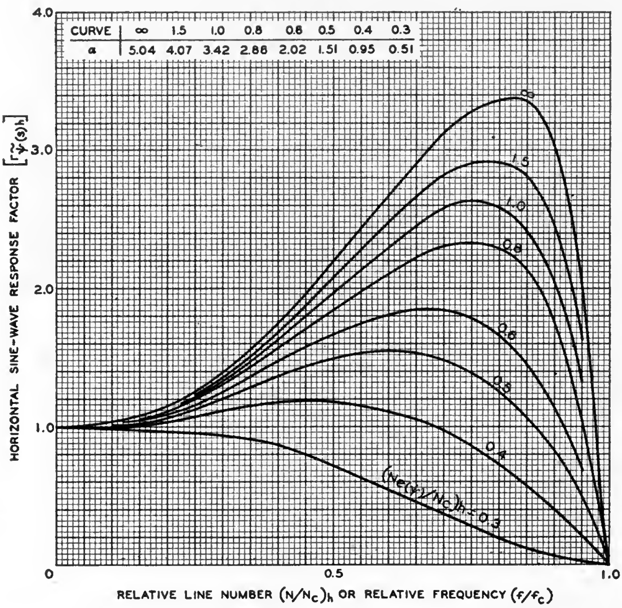


Fig. 87d. Normalized response characteristics for "flat" channel with gradual-cutoff filter (Fig. 82) in cascade with exponential apertures and 6× aperture correction (Fig. 81).

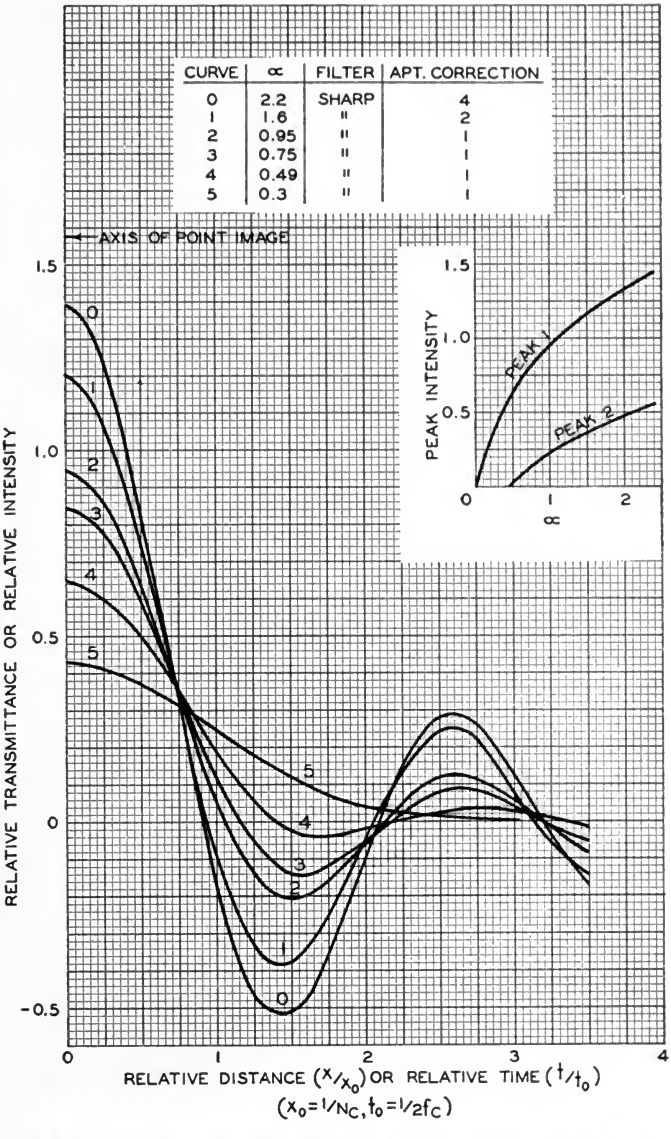


Fig. 88. Impulse forms or aperture transmittance obtained with response characteristics Figs. 86 and 87.

phase delay within the system passband. The aperture cross section (τ_h) depends, again, on the relative equivalent passband (α) as shown in Fig. 88.

Phase distortion between sine-wave components can occur in electrical and also in optical elements (lenses, etc.). In terms of aperture properties it is caused by an asymmetric aperture transmittance (coma for example) and results

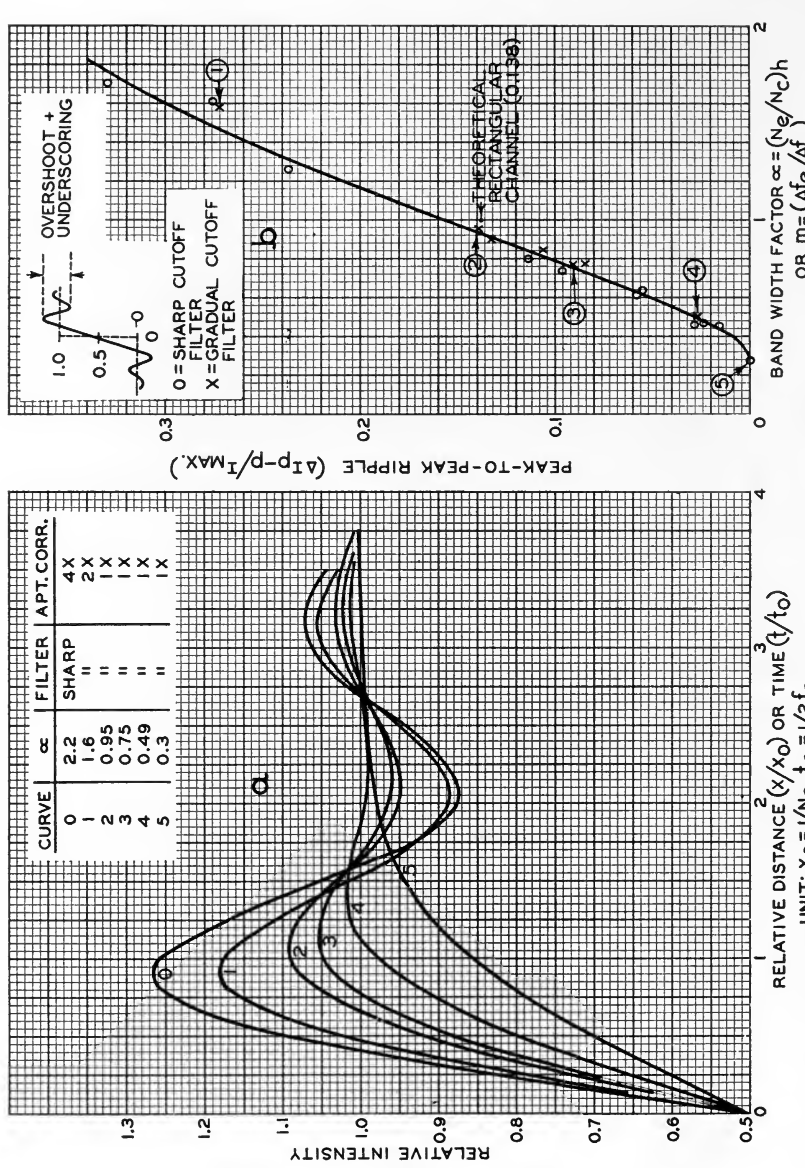


Fig. 89. Edge transitions and transient ripple obtained with response characteristics Figs. 86 and 87.

in asymmetric edge transitions. Phase distortion is of little importance in the transfer of random deviations, but it is an important aperture property determining waveform distortion. The measurement and effects of phase distortion will be discussed with the subjects of image sharpness and definition in Part IV of this paper.

The electrical response to a step function, or the corresponding electrooptical response to a sharp edge, is obtained by integration of

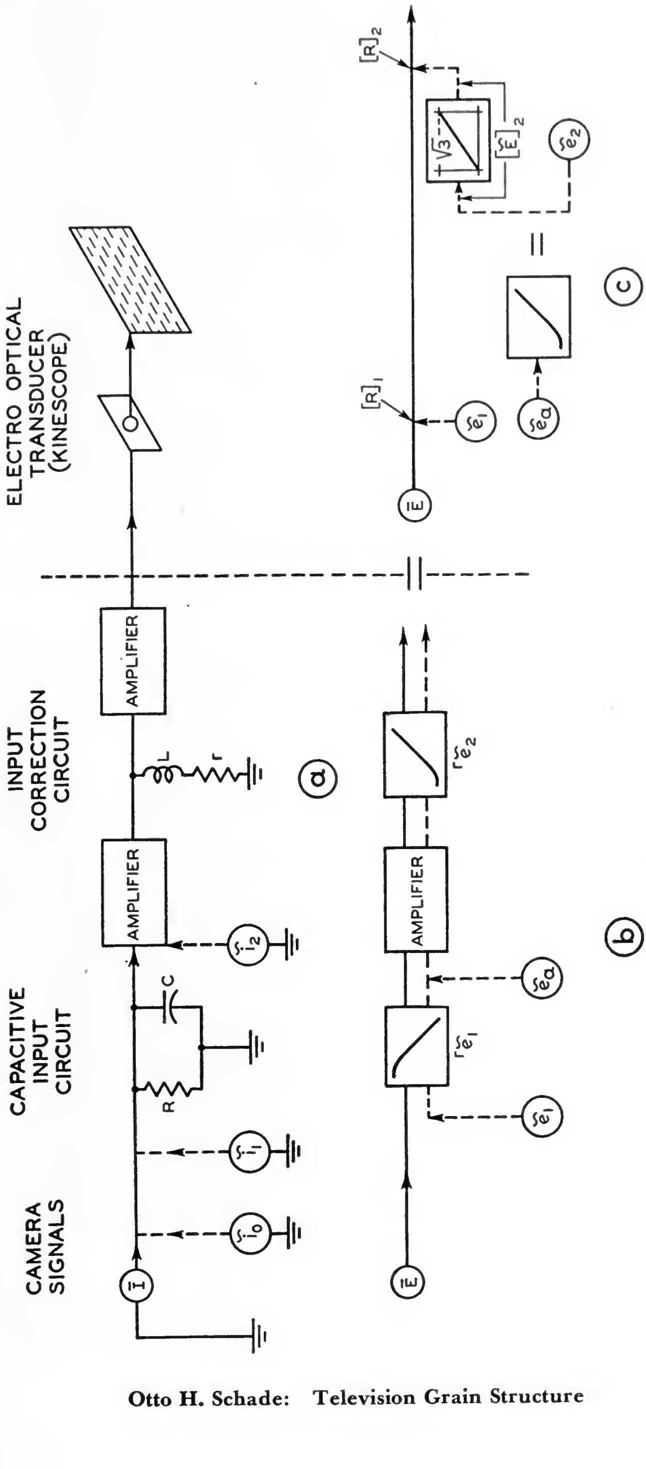


Fig. 90. Camera circuits and noise sources.

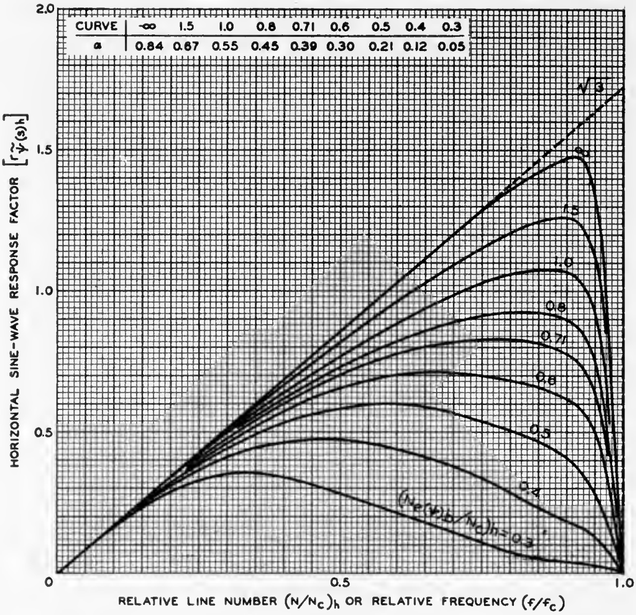


Fig. 91a. Normalized response characteristic for "peaked" channel with sharp-cutoff filter (Fig. 82) in cascade with exponential apertures and 1× aperture correction (Fig. 81).

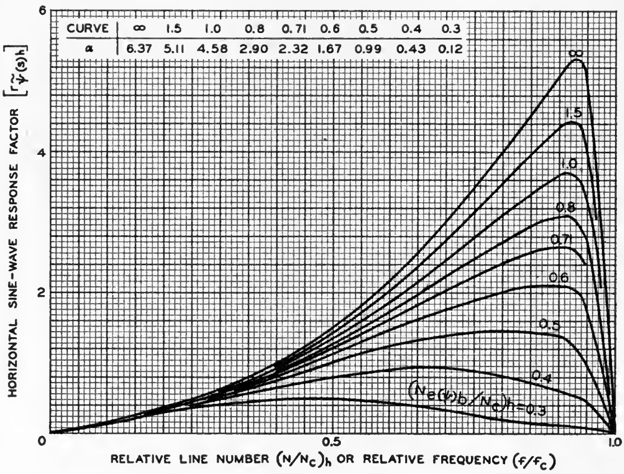


Fig. 91b. Normalized response characteristic for "peaked" channel with sharp-cutoff filter (Fig. 82) in cascade with exponential apertures and 4× aperture correction (Fig. 81).

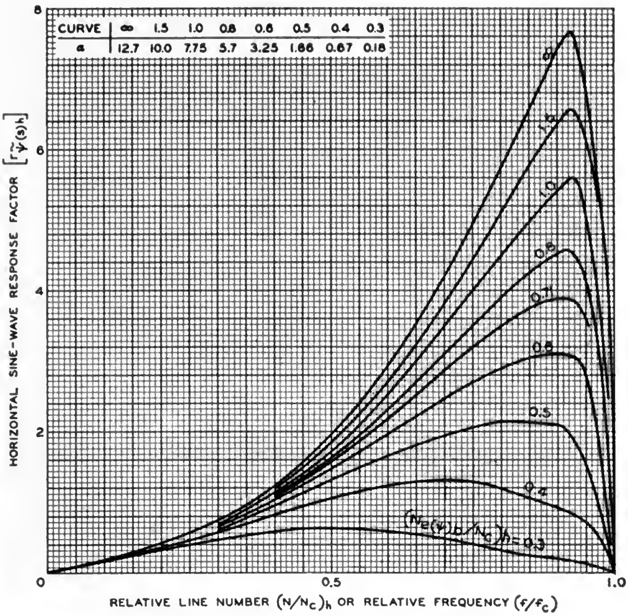


Fig. 91c. Normalized response characteristic for "peaked" channel with sharp-cutoff filter (Fig. 82) in cascade with exponential apertures and 6× aperture correction (Fig. 81).

the impulse function and shown in Fig. 89a for zero phase distortion. The normalizing or "filtering" effect of larger two-dimensional apertures (low α) in cascade with the "abnormal" electrical response characteristics is evident. *The peak-to-peak transient* ripple can be estimated from the α-value by the curve shown in Fig. 89b.

The response characteristics Figs. 86 and 87 include a complete video system and are required for calculation of signal-to-deviation ratios originating in electrical sources ahead of the video amplifier or in photographic grain patterns ahead of the television system. Fluctuations ($\tilde{\imath}_0$) (see Fig. 65) in the photo-emission current of the camera tubes are usually of negligible magnitude compared to fluctuations ($\tilde{\imath}_1$) originating in the camera tube beam-current or in the current of the first amplifier stage. (Fluctuations ($\tilde{e}_t$) introduced later in the process of signal transmission (radio links, etc.) vary in magnitude according to distance and will be assumed negligible in this analysis.) The location of the dominating source $\tilde{\imath}_1$ in the system is shown in more detail in Fig. 90a. The diagram Fig. 90b indicates the response characteristic $r_{\bar{e}1}$ of the capacitive input circuits in which the response decreases with frequency, and following the response characteristic $r_{\bar{e}2}$ (high-peaking circuit) by which the signal response is again corrected to a constant-amplitude response $r_{\bar{e}1}r_{\bar{e}2} = r_{\bar{e}12} = 1$. The equivalent diagram Fig. 90b illustrates that fluctuations $\tilde{e}_1$ originating in a camera tube have a constant-amplitude frequency spectrum and are termed *flat channel noise.* Fluctuations $\tilde{e}_a$ from the first video amplifier are modified in the input-correction circuit to have a sine-

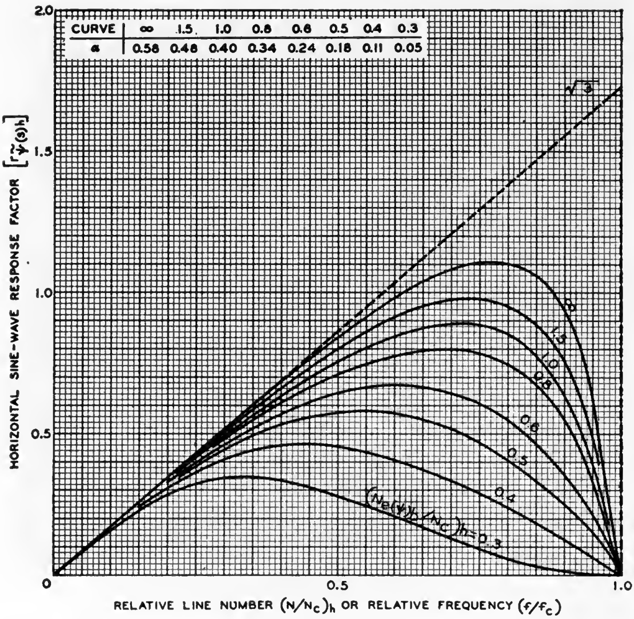


Fig. 92a. Normalized response characteristic for "peaked" channel with gradual-cutoff filter (Fig. 82) in cascade with exponential apertures and 1× aperture correction (Fig. 81).

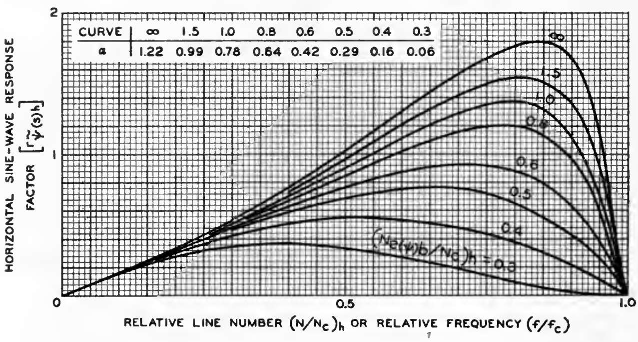


Fig. 92b. Normalized response characteristic for "peaked" channel with gradual-cutoff filter (Fig. 82) in cascade with exponential apertures and 2× aperture correction (Fig. 81).

wave spectrum with amplitudes proportional to frequency. *This type of fluctuation is termed peaked-channel noise.* The response factor of the theoretical triangular characteristic with sharp cutoff has been normalized to the value $r_{\tilde{e}1} = \sqrt{3}$ at $N = N_{c(h)}$ to obtain $N_{e1} = N_{c(h)}$ for the theoretical condition (see section D2.) In cascade with aperture correction circuits ($r_{\tilde{e}c}$), the cutoff filter ($r_{\tilde{e}f}$), and the apertures ($r_{\tilde{\psi}(b)}$) following the electrical system, the frequency spectrum

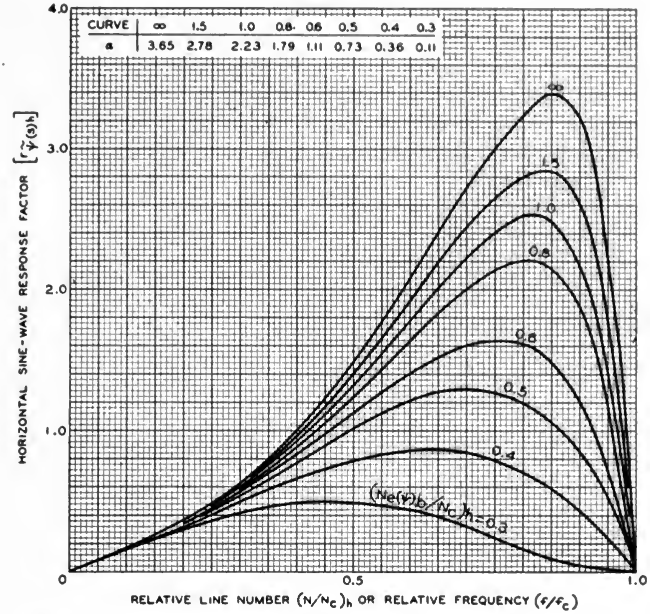


Fig. 92c. Normalized response characteristic for "peaked" channel with gradual-cutoff filter (Fig. 82) in cascade with exponential apertures and 4× aperture correction (Fig. 81).

for peaked channel noise is modified to the forms shown by the normalized response characteristics Figs. 91 and 92.

In the Fourier synthesis of the corresponding aperture transmittance (or impulse shape), the cosine terms are changed to negative sine terms because of a 90° phase shift in the reactive circuit (except for the lowest-frequency terms which can be neglected because of their small amplitude). The impulse waveform or horizontal-aperture transmittance of these characteristics is, therefore, a differentiated pulse as shown in Fig. 93 (obtained by differentiating the corresponding flat-channel pulse shapes (Fig. 88)).

4. Aperture Response of Camera Tubes and Kinescopes

The sine-wave response of *television camera tubes* is measured with the help of vertical and horizontal cross-section selector circuits[3] using sine-wave test patterns or a conversion from square-wave response characteristics. The sine-wave response is determined primarily by the aperture characteristic of an electron beam but is modified by a number of secondary aperture effects, such as image-plate granularity, out-of-focus conditions (particularly in iconoscope and image-iconoscope types which have inclined targets), or the aperture of electron-image sections.

The sine-wave response of camera tubes, decreases, therefore, more rapidly than that of a kinescope and the effective aperture is a composite of several exponential ($\epsilon^{-(r/r_c)^2}$) spot sizes. The sine-wave response of a typical camera tube is shown in Fig. 94. Although measured recently on image orthicons having 3-in. faceplates this characteristic may be regarded as typical of good commercial camera tubes in use at this time, includ-

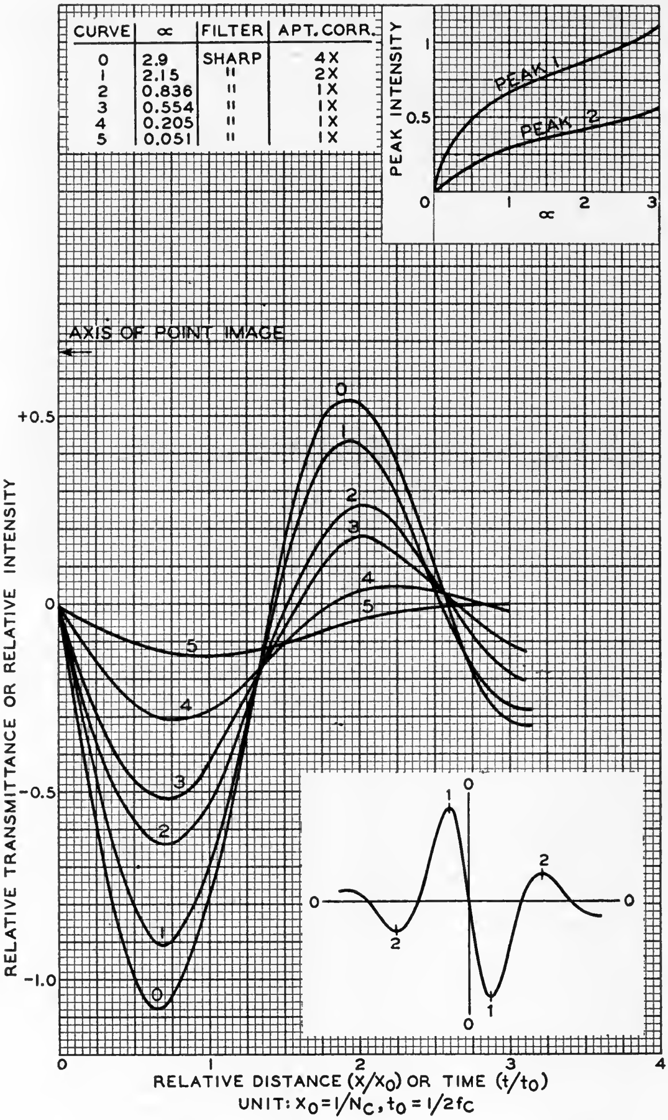


Fig. 93. Impulse forms or aperture transmittance obtained with response characteristics Figs. 91 and 92.

Table XVI. Equivalent Passband $\bar{N}_e$ and Approximate Limiting Resolution N_c of Television Components.

	$\bar{N}_e$	N_c*	r_ψ
Square spot $\tau = 1$	0.49 N_c*		Part II, Fig. 41
Round spot $\tau = 1$	0.45 N_c*		" " " 42
Round spot $\tau = \cos^2 r$	0.38 N_c*		" " " 43
Exponential spot $\tau = \epsilon^{-(r/ro)}$	0.23 N_c*		" " " 46a
Exponential spot $\tau = \epsilon^{-(r/ro)^2}$	0.32 N_c*		" " " 44
	0.20 N_c*		(av. field luminosity $B \simeq$
Eye at viewing ratio: $d/V = 2$	376	1880	4 to 10 ft-L)
4	188	940	Fig. 81
8	94	470	
Camera tubes	$\bar{N}_e$	N_c*	r_ψ
Image iconoscope	200	800 (approx.)	
Image orthicon (type 5826)	200	800 "	Fig. 94
Image orthicon 4½-in. faceplate	250	1300 "	" 95
Vidicon (type 6198)	158	650 "	" 96
Kinescopes	265	920 "	" 97
	420	1500 "	
	500	1800 "	
	800	3000 "	

N_c* at response $r_\psi \simeq 0.02$.

ing iconoscopes and European orthicon and image-iconoscope types.† According to the author's experience and measurements, there is no evidence supporting statements often found in the literature that high-velocity tubes, such as the iconoscope types, have higher resolution, i.e., a better response characteristic than low-velocity tubes. Theoretical advantages in one type are balanced by disadvantages imposed by tube geometry or auxiliary components in other types. The relative performance of different tubes is often thoughtlessly compared, disregarding large differences in the size of the storage surface and its capacitance. The response characteristics of an experimental high-definition image orthicon having a larger storage surface is shown in Fig. 95, and that of a small vidicon in Fig. 96 (both are low-velocity types).

The equivalent passband $\bar{N}_e$ of the characteristic in Fig. 94 is 200; this value may be regarded as representative of good commercial camera tube performance at the present time. Appropriate values for resolution (N_c) and equivalent passband N_e of camera tubes are listed in Table XVI.

The *sine-wave response characteristic of a kinescope* is shown in Fig. 97. The measured electrooptical response departs more or less from that of theoretical electron beams because of aberrations and the additional aperture effect of the particle structure of the screen phosphor. Uniformity of the response in the frame area and resolution depend on the design of the electron gun, electron lens, and the operating conditions. The resolution of kinescope types may vary from a few hundred to several thousand lines. The

† A recent publication[4] claims a resolution limit of 900 to 1000 lines for the center of a modern image iconoscope and about 700 lines at the edges. Low-velocity types have very little astigmatism and a substantially uniform spot diameter for correctly adjusted operating conditions.

response characteristic retains a shape similar to that in Fig. 97. Approximate values of the equivalent passband (N_e) and limiting resolution (N_c) for a variety of kinescopes are listed in Table XVI.

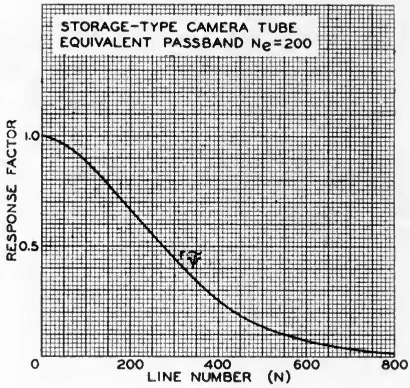
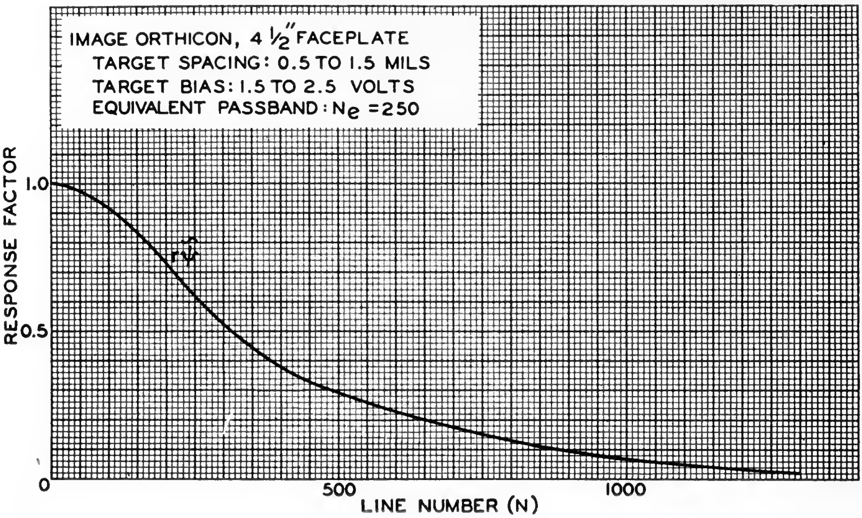


Fig. 94. Sine-wave response (r_ψ) of commercial camera tubes.

Fig. 95. Sine-wave response (r_ψ) of experimental high-definition camera tubes.



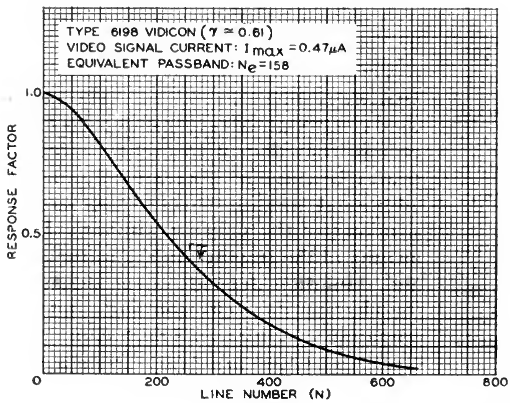


Fig. 96. Sine-wave response (r_ψ) of small camera tube (vidicon) with photoconductive target.

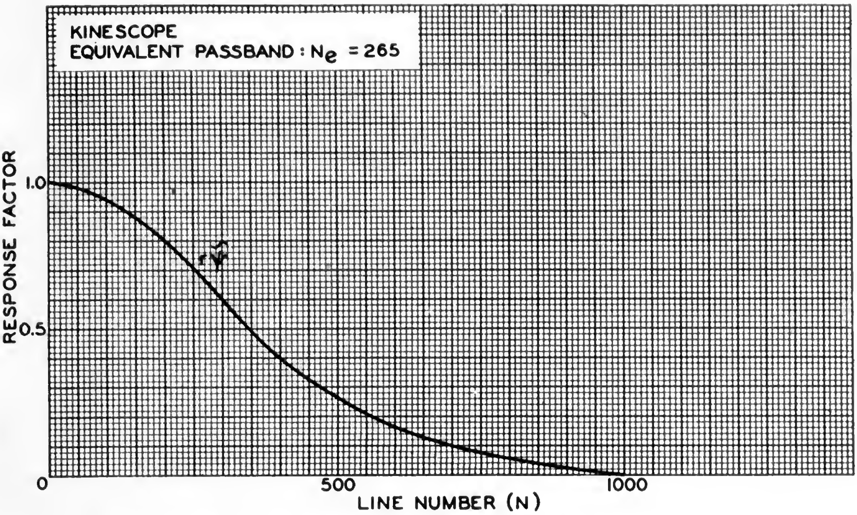


Fig. 97. Sine-wave response ($r_{\bar{\psi}}$) of a kinescope.

D. EQUIVALENT PASSBANDS AND SIGNAL-TO-DEVIATION RATIOS

1. General Formulation

The passband of an electrooptical system, such as a television system, has a definite value defined by the electrical cutoff frequency f_c, or more adequately by the passband $\bar{N}_{e(f)} = (N_{c(h)}n_r)^{\frac{1}{2}}$ of the theoretical measuring aperture. Because of the relation $f/f_c = N_{(h)}/N_{c(h)}$, frequencies and line numbers in the horizontal coordinate have been expressed in relative units $(N/N_c)_h$ permitting representation of the system response by generalized characteristics. *The equivalent horizontal passband $N_{e(s)h}$ of an electrooptical system* can hence be stated in the general form

$$N_{e(s)h} = \alpha N_{c(h)} \qquad (66)$$

where

$\alpha = \int_0^1 (r_{\bar{e}} r_{\bar{\psi}})^2_{(N/Nc)h}\, d(N/N_c)_h$ = relative equivalent passband

$r_{\bar{e}(f/fc)}$ = response characteristic of electrical system following source of deviations

$r_{\bar{\psi}(N/Nc)h}$ = response characteristic of aperture system following source of deviations.

The system response in the vertical coordinate is determined completely by the raster constant n_r and the two-dimensional apertures of the system, and has likewise been expressed in relative units N_v/n_r. *The equivalent vertical passband $N_{e(s)v}$* of the system, can hence be stated in the general form.

$$N_{e(s)v} = \beta n_r \qquad (67)$$

The relative equivalent passband $\beta = N_{e(s)v}/n_r$ is given by Eqs. (59), (60), or Fig. 76. For deviations of electrical origin, the analyzing aperture δ_a is the measuring aperture δ_f of the theoretical television system. (See section C2.) The equivalent vertical passband of $\delta_a = \delta_f$ is hence $N_{e(a)} = n_r$ and the vertical passband of the system is given exactly by Eq. (60), i.e., $N_{e(s)v} = N_{e(b)}$ and $\beta = N_{e(b)}/n_r$.

The factors α and β are defined by Eqs. (66) and (67) as ratios of the equivalent horizontal or vertical passband of the system to the corresponding theoretical passband of the television channel and are, therefore, termed *bandwidth factors*.

The equivalent symmetric passband $\bar{N}_{e(s)}$ of the system is the geometric mean of its equivalent horizontal and vertical passbands:

$$\bar{N}_{e(s)} = (\alpha\beta)^{\frac{1}{2}}(N_{e(h)}n_r)^{\frac{1}{2}} \qquad (68)$$

The corresponding bandwidth factor $(\alpha\beta)^{\frac{1}{2}}$ of the system is the geometric mean of the horizontal and vertical bandwidth factors.

By combining Eq. (68) with Eq. (53), the signal-to-deviation ratio $[R]_s$ at any point in an electrooptical system can be stated in the convenient form:

$$[R]_s = [R]_m(\bar{N}_{e(m)}/\bar{N}_{e(f)})/(\alpha\beta)^{\frac{1}{2}}\dot{\gamma}_s \qquad (69)$$

The meaning of the symbols is summarized for easy reference:

- $[R]_m$ = Signal-to-deviation or signal-to-noise ratio at origin of deviations
- $\bar{N}_{e(m)}$ = Equivalent passband of aperture with which $[R]_m$ is computed or measured
- $\bar{N}_{e(f)}$ = $(N_{e(h)}n_r)^{\frac{1}{2}}$ = theoretical aperture of television channel
- α = Horizontal bandwidth factor (Eq. (66))
- β = Vertical bandwidth factor (Eq. (67))
- $\dot{\gamma}_s$ = product of all point gammas between origin of deviation and point of observation.

Deviations may originate at a number of points in the electrooptical system indicated in Fig. 65. The deviations from the various sources are computed separately (compare Part II) and combined by forming their rms sum. *Deviations ($\bar{\psi}$) originating in the grain structure of a preceding motion-picture process* are transferred through the entire television system and observed in the final image. *Fluctuations originating in the electrical system* are displayed likewise as two-dimensional deviations in a picture frame, but they are also observed and measured as *signal-to-noise ratios* at various points of the electrical system. In all cases the signal-to-deviation ratio $[R]_s$ or signal-to-noise ratio $[R]$ may be computed with Eq. (69) by determining the proper reference values, bandwidth factors, and point gammas of the system elements involved in the transfer of signals and deviations.

2. The Reference Values $[R]_m$ and $\bar{N}_{e(m)}$

The signal-to-deviation ratio at the source is either computed or determined by measurements with an aperture of known equivalent passband $\bar{N}_{e(m)}$. *Optical deviations $\bar{\psi}$* originate in a photographic system preceding the television process and appear in the projected film image (A_0 in Fig. 65) which can be regarded as the source of deviations. In a motion-picture transmission by a television system, the normal motion-picture projection lens δ_3 is replaced by the lens δ_0 of the television film camera (Fig. 65). When the lenses are of equal quality ($\delta_0 = \delta_3$), the measuring aperture is simply $\bar{N}_{e(m)} = \bar{N}_{e(p)}$, and the reference signal-to-deviation ratio is $[R]_m = [R]_p$, where $\bar{N}_{e(p)}$ and $[R]_p$ are the equivalent passband and signal-to-deviation ratio of the normal motion-picture process as computed in Part II. When the lenses are not identical, $\bar{N}_{e(m)}$ can be computed with $1/\bar{N}_{e(m)}^2 = (1/\bar{N}_{e(p)}^2) - (1/\bar{N}_{e(3)}^2) + (1/\bar{N}_{e(0)}^2)$ and

$$[R]_m = [R]_p(\bar{N}_{e(m)}/\bar{N}_{e(p)})\dot{\gamma}_2/\dot{\gamma}_0 \qquad (70)$$

Electrical fluctuations $\bar{i}_0$ in photoelectric currents are normally computed from the number of electrons emitted in a time unit. The signal-to-noise ratio $[R]_0 = [R]_m$ can be obtained by the equivalent two-dimensional formulation given by Eq. (52) where $\bar{n}_0$ is the number of electrons, i.e., the total charge $Q_f/(H/V)$ in the unit area divided by the charge (q_e) of one electron:

$$[R]_m = [R]_0 = \left(\frac{Q_f}{q_e(H/V)}\right)^{\frac{1}{2}}/N_{e(m)} \qquad (71)$$

with the frame charge $Q_f = I_0T_fb$ amp sec the electron charge $q_e = 1.6 \times 10^{-19}$ amp sec and the measuring aperture $\bar{N}_{e(m)} = \bar{N}_{e(f)}$ of the theoretical television channel:

$$[R]_0 = \left(\frac{I_0 T_f b\ 10^{19}}{1.6(H/V)}\right)^{\frac{1}{2}} / \bar{N}_{e(f)} \quad (72)$$

where

I_0 = photo current (amp)
T_f = frame time ($\frac{1}{30}$ sec)
b = $(1 - b_h)(1 - b_v)$ = blanking factor ($b = 0.785$)
H/V = aspect ratio ($H/V = 4/3$)
$\bar{N}_{e(f)} = (N_{e(h)} n_r)^{\frac{1}{2}}$ (see Eq. (64)).

Fluctuations $\tilde{\imath}_1$ *in the beam current of television camera tubes* can be computed similarly from the values of beam current and storage capacitance of the tube.[3] A reference signal-to-noise ratio $[R]$ is usually given by the manufacturer for a specified frequency channel Δf_s. The reference values for a frequency channel Δf are therefore:

$$[R]_m = [R]_1 = [R](\Delta f_s/\Delta f)^{\frac{1}{2}} \quad (73)$$

and

$$\bar{N}_{e(m)} = \bar{N}_{e(f)}$$

Camera tubes not having an electron multiplier, such as iconoscopes, image iconoscopes, orthicons (C.P.S. Emitron) and vidicons, require the use of high-gain camera amplifiers. *The current fluctuations* $\tilde{\imath}_2$ *in the first amplifier tube* become the dominant noise source. All high-gain camera amplifiers have a capacitive input circuit (Fig. 90a) which causes the signal-input voltage on the first amplifier tube to decrease with frequency as indicated in the voltage diagram Fig. 90b. The decreasing sine-wave response $r_{\bar{z}1}$ is, therefore, compensated by a corrective network ($r_{\bar{z}2}$) to a constant signal response $r_{\bar{z}1}r_{\bar{z}2} = 1$. The noise voltage $\tilde{e}_a$ generated by the first amplifier current $\tilde{\imath}_2$ is inserted between the input and correction circuits, and its normal "flat" spectrum is modified by the response $r_{\bar{z}2}$ to a spectrum with rising amplitude response termed a "peaked" channel. The amplifier circuit can, therefore, be represented as a flat (compensated) signal channel ($r_{\bar{z}12} = 1$) into which a noise voltage $\tilde{e}_a$ is introduced over a peaked channel as indicated by the equivalent voltage diagram Fig. 90c. The rms-value $[\tilde{E}]_a$ of the flat-channel noise voltage $\tilde{e}_a$ can be computed in first approximation from the "equivalent noise resistance" R_{eq} of the amplifier tube[5] and has the value

$$[\tilde{E}]_a = 1.3 \times 10^{-10}(R_{eq}\Delta f)^{\frac{1}{2}} \quad (74)$$

The corrective network $r_{\bar{z}2}$ changes this value by the factor

$$a_2 = [\tilde{E}]_2/[\tilde{E}]_a = \left[\int_0^1 (g/g_0)^2_{(f/f_c)} d(f/f_c)\right]^{\frac{1}{2}} \quad (75)$$

which is the *rms value* of the gain ratio (g/g_0) in the network. In terms of circuit constants the gain ratio is equal to the impedance ratio $\omega L/r$, which in turn must equal the time constant ωCR of the input circuit to obtain a complete compensation $r_{\bar{z}1}r_{\bar{z}2} = 1$. Integration furnishes the value

$$a_2 = (\omega_c CR/\sqrt{3}) = 2\pi\Delta f CR/\sqrt{3} \quad (76)$$

where

C = effective capacitance of input circuit in farads
R = shunt resistance of input circuit in ohms.

For a general formulation it is expedient to replace the actual noise source $\tilde{e}_a$ and the correcting circuit by a noise source $\tilde{e}_2$ generating the rms voltage $[\tilde{E}]_2$ in a flat channel Δf and to change the spectrum to a "peaked" frequency spectrum by a correction network having a normalized response characteristic and the response factor $r_{\bar{z}2} = \sqrt{3}$ at $f = f_c$. *The normalized characteristic* $r_{\bar{z}2}$ (see broken-line curve in Fig. 91a) does not change the rms value $[\tilde{E}]_2$, because for $r_{\bar{z}2} = \sqrt{3}$ at f_c, the rms voltage ratio of the normalized correction network has the value

$$[\tilde{E}]_2/[\tilde{E}]_a = \left[\int_0^1 (r_{\bar{z}_2})^2_{(f/f_c)} d(f/f_c)\right]^{\frac{1}{2}} = 1 \quad (77)$$

The signal-to-noise ratio $[R]_2$ for amplifier noise (equivalent circuit Fig. 90c) is computed as follows:

The signal is the voltage $\bar{I}R$ developed

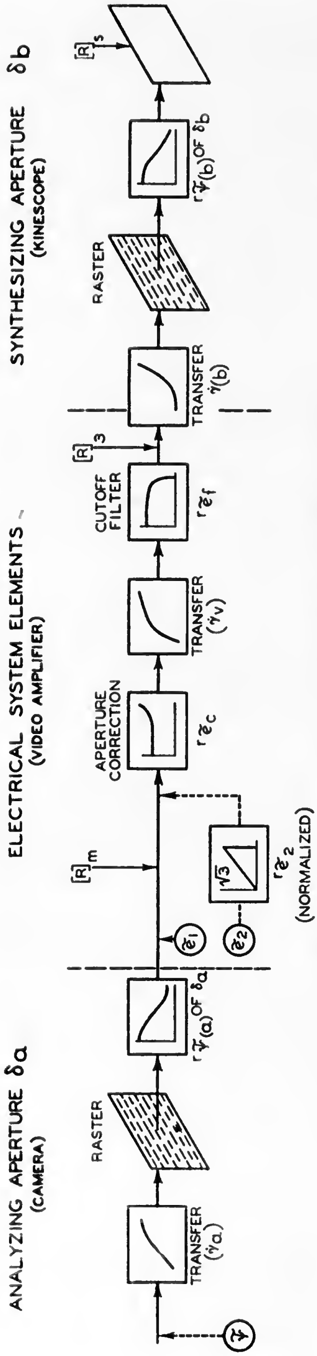


Fig. 98. Noise sources and elements of television process.

by the camera-tube signal current $\bar{I}$ in the input resistance R (Fig. 90a), because the effect of the shunt capacitance C has been compensated by a corrective network. The noise source is considered as a flat-channel noise source having an rms voltage $[\tilde{E}]_2 = a_2[\tilde{E}]_a$. Because of Eq. (77) the noise voltage after the peaking circuit has the same rms value. The measuring aperture for the normalized circuit has the equivalent passband $\bar{N}_{e(m)} = \bar{N}_{e(f)}$ and the signal-to-noise ratio is $[R]_2 = \bar{I}R/a_2[\tilde{E}]_a$. With the values of Eqs. (74) and (76):

$$[R]_2 = 2.13\bar{I} \times 10^9/C(R_{eq})^{\frac{1}{2}}(\Delta f)^{\frac{3}{2}} \qquad (78)$$

The signal-to-noise ratio $[R]_2$ of practical amplifier circuits may have a lower value than the one computed with Eq. (78) which neglects noise contributed by circuit resistances, subsequent amplifier stages, and the effects of feedback. These contributions are usually small for circuits using a pentode input stage (type 6AC7). They are appreciable for a normal triode input stage but may be minimized by the use of special circuits and tubes having low grid-plate capacitance. A typical input stage used in older camera amplifiers uses a type 6AC7 amplifier tube as a pentode with the following constants:

$$R_{eq} = 720 \text{ ohm}, \; C = 30 \times 10^{-12} \text{ farad}, \; R = 10^5 \text{ ohm}$$

The maximum signal current $\bar{I}_{(\max)}$ from camera tubes not having an electron multiplier is of the same order: $\bar{I}_{(\max)} \simeq 0.1 \times 10^{-6}$ amp. With these values Eq. (78) furnishes the value $[R]_{2\max} = 30$ in a frequency channel $\Delta f = 4.25 \times 10^6$ cycles/sec.

Modern high-gain camera amplifiers use special high-transconductance triodes with a somewhat higher effective capacitance but a much lower equivalent noise resistance $R_{eq} \simeq 110$ ohm in a "cascode" circuit, resulting in an improved signal-to-noise ratio $[R]_{2\max} \simeq 70$ for $\Delta f = 4.25 \times 10^6$ cycles/sec. The variation of $[R]_2$ as a function of signal current, frequency channel or other parameters is readily computed with Eq. (78). Reference values for various camera-tube types are listed in Table XVII.

3. Bandwidth Factors

The ratios of the equivalent passbands of an electrooptical system to the theoretical equivalents $N_{e(h)}$ and n_r of its electrical system (Eqs. (66), (67), (68)) have been termed bandwidth factors. A system containing two-dimensional apertures has horizontal and vertical bandwidth factors α and β and its equivalent symmetric aperture has a bandwidth factor $(\alpha\beta)^{\frac{1}{2}}$ which is their geometric mean. *The horizontal bandwidth factor* α includes the response r_{ψ} of two-dimensional apertures as stated by Eq. (66). It is used to compute the signal-to-deviation ratio in the final image frame for deviations originating (1) in a photographic process ahead of the television system or (2) in electrical noise sources. In case 1 the two-dimensional aperture response is $r_{\psi} = (r_{\psi(a)} r_{\psi(b)})$. In case 2, $r_{\psi} = r_{\psi(b)}$, because only apertures following the electrical network are in the system ($r_{\psi(b)}$ may include the response of the eye). Integration of the squared normalized response characteristics Figs. 86 and 87 furnishes electrooptical bandwidth factors α for case 1 and for case 2 with electrical flat channel noise sources $\tilde{e}_1$. For convenience in plotting, the corresponding square roots $\alpha^{\frac{1}{2}}$ are shown in Fig. 99. The bandwidth factors for peaked channel noise sources $\tilde{e}_2$ have been computed similarly for the characteristics Figs. 91 and 92, and their square roots are shown in Fig. 100.

For deviations ψ of optical origin, the vertical bandwidth factor β may be obtained from Fig. 76 or computed with Eqs. (59) or (60). For deviations of electrical origin ($\tilde{e}_1$ or $\tilde{e}_2$) the exact value of the vertical bandwidth factor of the system is given by

$$\beta = (N_{e(b)}/n_r) \qquad (81)$$

It has been shown that the electrical circuit response of a television system has no effect on the vertical aperture response of the system. The vertical bandwidth factor β of electrical elements is, therefore, $\beta = 1$. The bandwidth fac-

Table XVII. Maximum Signal-to-Noise Ratios $[R]_{m\,(\max)}$ of Various Camera-Tube Types for Theoretical Channel $\Delta f = 4.25$ Mc.

Tube type	Use	Approx. target capacitance ($\mu\mu f$)	$\hat{I}(\mu a)$	$[R]_{m\,\max}$	Noise** source	Spectrum
Iconoscope	Film Pickup	10000	0.1	70	$\tilde{e}_2$	peaked
Vidicon type 6198	Film "	2200	0.45	315	$\tilde{e}_2$	peaked
Image iconoscope	Live "	6000	0.1	70	$\tilde{e}_2$	peaked
Orthicon* (without multiplier)	Live "	700	0.1	70	$\tilde{e}_2$	peaked
Image orthicon						
Type 5820	Live "	100	10	34	$\tilde{e}_1$	flat
5826	Live "	375	10	66	$\tilde{e}_1$	flat
High-definition (4½-in. faceplate) image orthicon	Live "	1100	20–40	120	$\tilde{e}_1$	flat

* Similar to C.P.S. Emitron.

** See Fig. 98.

Note: $[R]_{m\,\max}$ for $\tilde{e}_2$ is obtained only with modern cascode input circuits (see text).

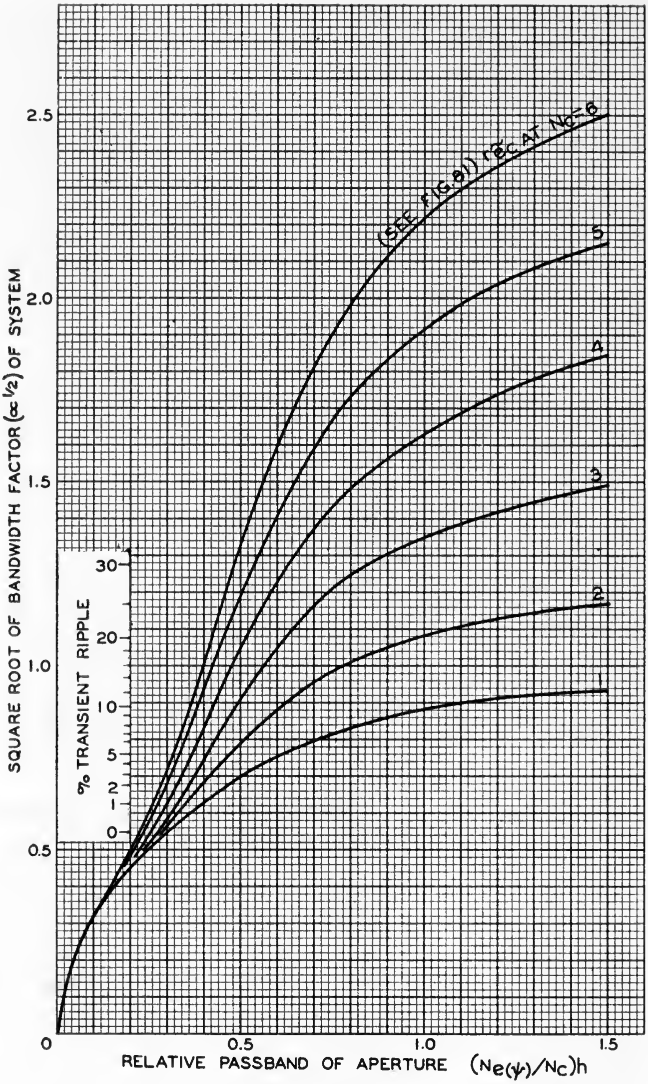


Fig. 99a. Bandwidth factors for "flat" channel noise sources with sharp-cutoff filter (Fig. 82) and aperture correction (Fig. 81) in cascade with exponential aperture.

tor $(\alpha\beta)^{\frac{1}{2}}$ of the equivalent aperture of electrical networks in an electrooptical system (excluding optical elements) has, therefore, a value $m^{\frac{1}{2}} = \alpha^{\frac{1}{2}}$, i.e., it is equal to the square root of its horizontal bandwidth factor m. The new symbol m is introduced to avoid confusion and indicate that this factor is reserved for purely electrical systems. According to Eq. (66), *electrical bandwidth factors* m are defined by

$$m = (\Delta f_e/\Delta f) = \int_0^1 (r_{\tilde{e}})^2_{(f/f_c)} d(f/f_c) \quad (79)$$

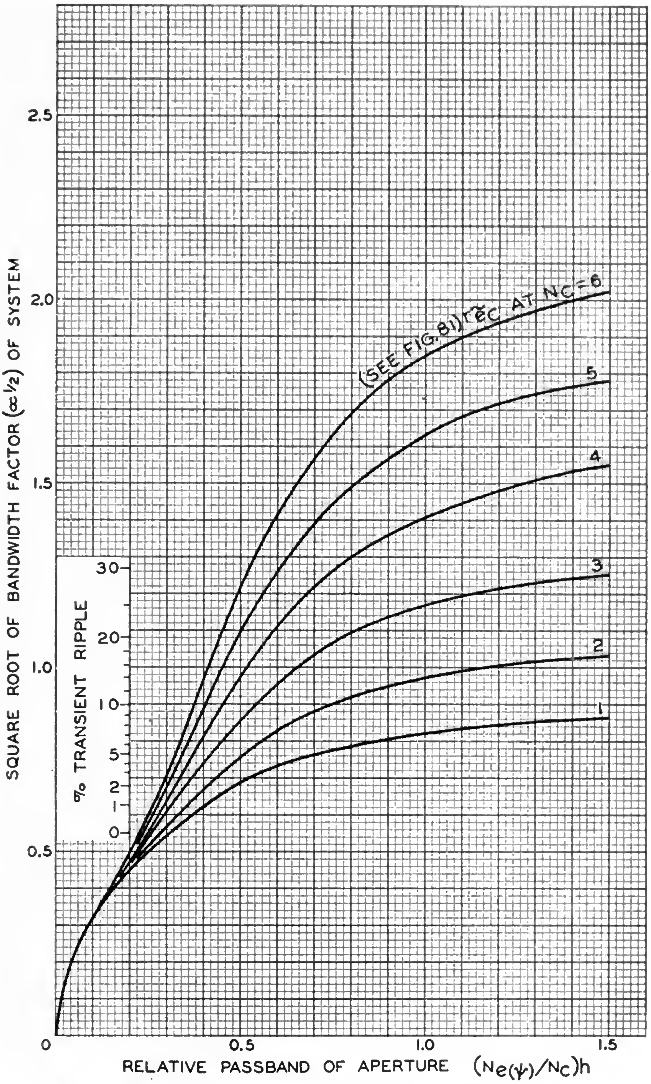


Fig. 99b. Bandwidth factors for "flat" channel noise sources with gradual-cutoff filter (Fig. 82) and aperture-correction circuits (Fig. 81) in cascade with exponential apertures.

where

Δf_e = noise-equivalent passband of the electrical system

Δf = theoretical (rectangular) passband of electrical system

$r_{\tilde{e}}$ = sine-wave response factor of electrical system.

4. Signal-to-Noise Ratios in the Electrical System

The signal-to-noise ratio $[R]$ at different points in the electrical system (compare Eq. 69) reduces to

$$[R] = [R]_m/m^{\frac{1}{2}}\dot{\gamma}_v \quad (80)$$

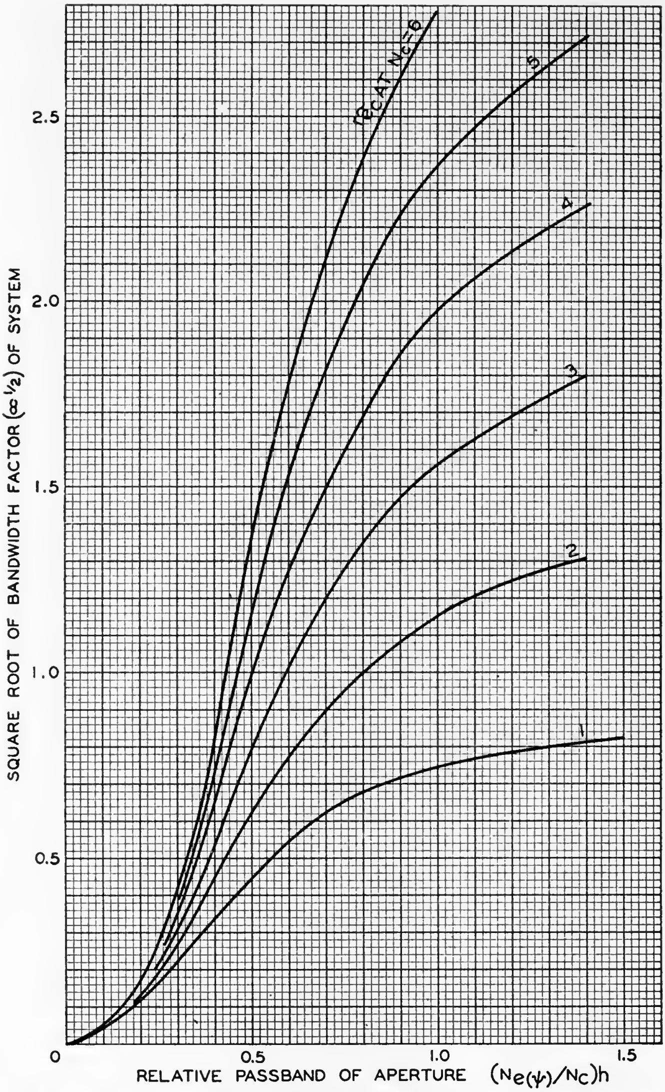


Fig. 100a. Bandwidth factors for "peaked" channel noise sources with sharp-cutoff filter (Fig. 82) and aperture correction (Fig. 81) in cascade with exponential apertures.

where

$[R]_m$ = signal-to-noise ratio computed for the theoretical passband Δf at the point of noise insertion (see preceding section)

m = electrical bandwidth factor computed for the frequency response $r_{\bar{z}}$ between the noise source and the point of observation (Eq. (79))

$\dot{\gamma}_v$ = point gamma of video amplifier between noise source and point of observation.

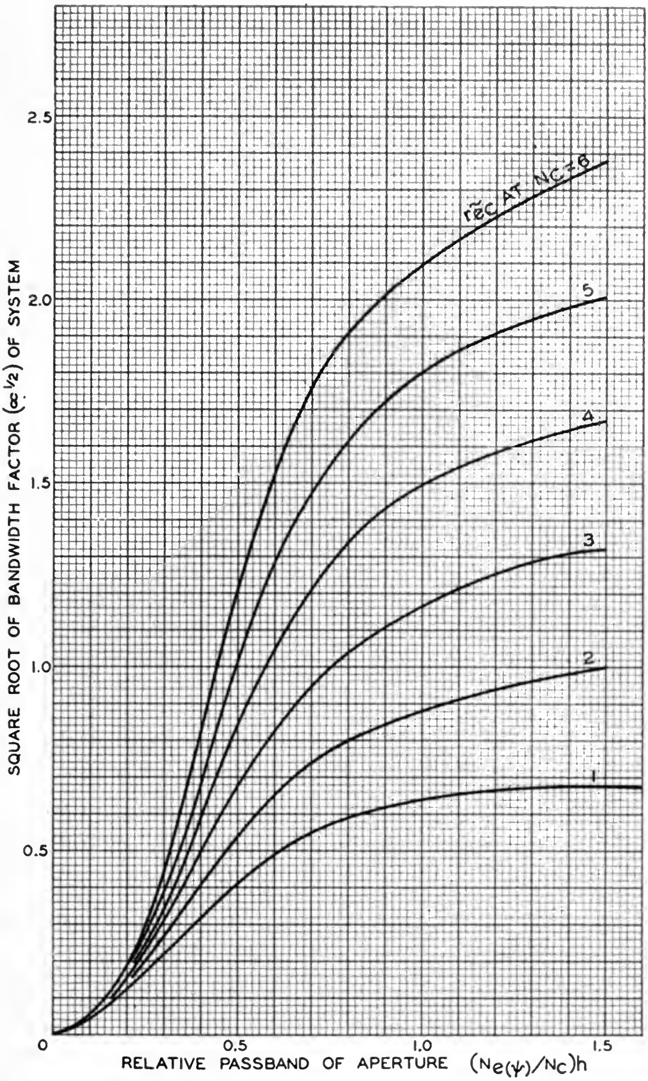


Fig. 100b. Bandwidth factors for "peaked" channel noise sources with gradual-cutoff filter (Fig. 82) and aperture correction (Fig. 81) in cascade with exponential apertures.

Actual measurements of the electrical signal-to-noise ratio are necessarily made at points following a cutoff filter, indicated in Fig. 98 by the index number 3. Figure 98 indicates all important electrical sources, the characteristics of the electrical system and the succeeding aperture system δ_b. The square roots $m^{\frac{1}{2}}$ of the bandwidth factors for circuit elements between the noise sources $\tilde{e}_1$ (camera tube noise) or $\tilde{e}_2$ (amplifier noise) have been computed for two filter

Table XVIII. Square Roots of Electrical Bandwidth Factors $m^{\frac{1}{2}}$.

Cutoff filter (Fig. 82)	Aperture correction at N_c (Fig. 81)	Noise source $\tilde{e}_1$ (flat spectrum) $m_{13}^{\frac{1}{2}}$	Noise source $\tilde{e}_2$ (peaked spectrum) $m_{23}^{\frac{1}{2}}$
Sharp	1 ×	0.98	0.914
"	2 ×	1.26	1.47
"	3 ×	1.63	2.0
"	4 ×	2.02	2.52
"	5 ×	2.4	3.04
"	6 ×	2.76	3.57
Gradual	1 ×	0.90	0.76
"	2 ×	1.09	1.10
"	3 ×	1.36	1.50
"	4 ×	1.68	1.91
"	5 ×	1.99	2.31
"	6 ×	2.24	2.70

characteristics ($r_{\tilde{e}f}$) and four values of aperture correction ($r_{\tilde{e}c}$), and are listed in Table XVIII.

The calculation of signal-to-noise ratios $[R]$ in the electrical system and signal-to-deviation ratios $[R]_s$ in the final image by means of Eqs. (80) and (69) respectively, is now a simple operation because the bandwidth factors m, α, and β or their square roots have been tabulated or plotted. The values $[R]_s$ change with signal level and point gamma ($\dot{\gamma}$) as in photographic systems. A comparison requires, therefore, evaluation of the *signal-to-deviation characteristic* $[R]_s$ as a function of screen luminance.

E. THE SIGNAL-TO-DEVIATION CHARACTERISTIC $[R]_s = f(B)$ OF TELEVISION PICTURE FRAMES

Television-signal generators and camera tubes may be divided into two groups. One group, including light-spot scanners (flying-spot scanner) and image-dissector tubes, has no charge-storing elements and operates without auxiliary currents. The photoelectric signals are amplified by built-in electron multipliers and have a sufficiently large magnitude to make the noise contribution by amplifier tubes negligible. The signal-to-noise ratio $[R]_m$ is therefore a function of the *photocurrent* only (Eq. 72) and varies as the half power of the signal current:

$$[R]_m = [R]_0 = [R]_{0\,\max}(I/\hat{I})^{\frac{1}{2}} \quad (82)$$

The second group of camera tubes has charge-storing elements (mosaics or targets), and employs electron beams for signal development. This group includes camera tubes having photo-emissive surfaces such as are used in the iconoscope, image iconoscope, orthicon and image orthicon, or photoconductive layers as used in the vidicon. The image orthicon is the only type in use having a built-in electron multiplier. It can, therefore, develop large signals and has a "flat" noise spectrum like that of multiplier phototubes. The signal-to-noise ratio $[R]_m = [R]_1$, however, varies in direct proportion to the signal current, because the dominant noise source is the *constant-beam current*

$$[R]_m = [R]_1 = [R]_{1\,\max}(I/\hat{I}) \quad (83a)$$

The camera tubes not having electron multipliers (iconoscope and orthicon and vidicon types) have a relatively small signal-current output. Their signal-to-noise ratio $[R]_m = [R]_2$ is controlled by the constant *amplifier noise* (Eq. (78))

which has a "peaked" frequency spectrum and $[R]_2$ varies in proportion to the signal current:

$$[R]_m = [R]_2 = [R]_{2\,\max}(I/\hat{I}) \quad (83b)$$

The optical signal-to-deviation ratio $[R]_s$ *in one picture frame* is computed with Eq. (69). With the substitutions from Eqs. (82) or (83) for $[R]_m$, and with $\bar{N}_{e(m)} = \bar{N}_{e(f)}$, the optical signal-to-deviation ratio for the first group of signal sources may be written:

$$[R]_s = [R]_{0\,\max}(I/\hat{I})^{\frac{1}{2}}/(\alpha\beta)^{\frac{1}{2}}\dot{\gamma}_v\dot{\gamma}_b \quad (84)$$

and for the second group of storage tubes:

$$[R]_s = [R]_{1\,\max}(I/\hat{I})/(\alpha\beta)^{\frac{1}{2}}\dot{\gamma}_v\dot{\gamma}_b \quad (85a)$$

and

$$[R]_s = [R]_{2\,\max}(I/\hat{I})/(\alpha\beta)^{\frac{1}{2}}\dot{\gamma}_v\dot{\gamma}_b \quad (85b)$$

where

- $\dot{\gamma}_v$ = point gamma of video amplifier system
- $\dot{\gamma}_b$ = point gamma of succeeding aperture processes including kinescope ($\dot{\gamma}_2$)
- $[R]_0$ and $[R]_1$ = signal-to-noise ratios with "flat" noise spectrum
- $[R]_2$ = signal-to-noise ratio with "peaked" noise spectrum

1. Effect of Transfer Characteristics and Point Gamma on $[R]_s$

The relation of luminance (B) in a picture frame to the signal current I and scene luminance or camera-tube exposure (E_1) is determined by the transfer characteristics of the system elements. A valid comparison of the signal-to-deviation ratios obtained with different television-camera types requires that the overall transfer characteristic (tone scale) of the system be identical. This requirement is met when the point gammas $\dot{\gamma}_T = \dot{\gamma}_1\dot{\gamma}_v\dot{\gamma}_b$ of the television systems are alike at the same luminance values. It is of interest to examine first the general effect of the camera-tube gamma ($\dot{\gamma}_1$) on the shape of the signal-to-deviation characteristic $[R]_s = f(B)$, which determines the relative visibility of deviations in the luminance range.

The $[R]_s$-characteristic can have different shapes depending on the camera-tube gamma ($\dot{\gamma}_1$), even though the overall gamma of the television system has fixed values $\dot{\gamma}_T$.

(*a*) *The Relative Signal-to-Deviation Ratios* $[R]_s/[R]_{\max}$ *of Constant Gamma Systems With Camera Tubes Having Constant Gamma.* It is assumed that the system gamma γ_T as well as the camera-tube gamma $\dot{\gamma}_1$ have constant values. The relative-signal current of the camera tube is then simply $I/\hat{I} = (E_1/\hat{E}_1)^{\gamma_1}$, where $(E_1/\hat{E}_1)$ is the relative exposure. With this relation and the substitutions $\dot{\gamma}_v\dot{\gamma}_b = \gamma_T/\gamma_1$ Eq. (85a) takes the form:

$$[R]_s = [R]_{1\,\max}(E_1/\hat{E}_1)^{\gamma_1}/(\alpha\beta)^{\frac{1}{2}}$$

In terms of screen luminance $(B/\hat{B}) = (E_1/\hat{E}_1)^{\gamma_T}$, this expression may be written

$$[R]_s = [R]_{1\,\max}(B/\hat{B})^{\gamma_1/\gamma_T}(\gamma_1/\gamma_T)/(\alpha\beta)^{\frac{1}{2}} \quad (86)$$

Inspection of Eq. (86) shows that the slope of the $[R]_s$-characteristic is controlled by the exponent (γ_1/γ_T) of the relative screen luminance $(B/\hat{B})$. A plot of Eq. (86) furnishes straight-line characteristics in log coordinates with a maximum value $[R]_s/[R]_{1\,\max} = (\gamma_1/\gamma_T)/(\alpha\beta)^{\frac{1}{2}}$ at $(B/\hat{B}) = 1$ and the constant slope (γ_1/γ_T) as shown in Fig. 101 for $(\alpha\beta) = 1$ and an overall constant gamma $\gamma_T = 1.2$. It is seen from Fig. 101 that only a minor improvement of $[R]_s$ is obtained in the shadow tones $B/\hat{B} = 0.01$ to 0.04 by decreasing γ_1 below the value $\gamma_1 = 0.6$ at the expense of a larger reduction of $[R]_s$ in the highlight values $B/\hat{B} = 0.2$ to 1. The preferred camera-tube gamma for a constant-system gamma $\gamma_T = 1.2$ is therefore γ_1 optimum $\simeq 0.6$.

(*b*) *The relative signal-to-deviation ratios* $[R]_s/[R]_{\max}$ *of systems with variable gamma.* It is impractical and actually undesirable to provide a constant overall gamma for the television system because of the finite limits imposed on the tone range by all practical imaging devices. According to photographic experience

Table XIX. Relative Signal-to-Deviation Ratios $[R]_s/[R]_{1\ max}$ for Image Orthicon (Also Iconoscope Film Pickup)* With Linear Amplifier ($\gamma_v = 1$), Kinescope Bias $E_0/\hat{E} = 0.13$ (Fig. 21, Part I) and $\alpha\beta = 1$.

$E_1/\hat{E}_1$	$I/\hat{I}$	$B/\hat{B}$	$\dot{\gamma}_v\dot{\gamma}_2$	$[R]_s/[R]_{1\ max}$	$\dot{\gamma}_1$	$\dot{\gamma}_T$
0.01	0.026	0.015	0.17	0.153	1.15	0.20
0.02	0.057	0.0185	0.40	0.142	1.15	0.46
0.04	0.125	0.031	0.95	0.132	1.10	1.045
0.07	0.22	0.06	1.45	0.152	0.85	1.23
0.10	0.295	0.095	1.70	0.174	0.75	1.275
0.20	0.47	0.22	1.90	0.247	0.58	1.10
0.40	0.69	0.46	2.00	0.345	0.49	0.98
0.70	0.88	0.77	2.05	0.429	0.39	0.80
1.00	1.00	1.00	2.10	0.476	0.31	0.65
(1)	(1)(2)	(2)	(3)	(4)	(5)	

Notes: (1) From Fig. 6, Part I. (2) From Fig. 21, Part I, ($I/\hat{I} = E/\hat{E}$). (3) $\dot{\gamma}_v = 1$. (4) Eq. (83a). (5) From Fig. 7, Part I.

* Transfer characteristic for $E_1 \simeq 15$, Fig. 11, Part I.

Table XX. Relative Signal-to-Deviation Ratios $[R]_s/[R]_{2\ max}$ for Image Iconoscope, and Orthicon ($\gamma_1 = 1$).

	Image iconoscope*				Orthicon, linear vidicon, $\gamma_1 = 1$		
$E_1/\hat{E}_1$	$I/\hat{I}$	$\dot{\gamma}_1$	$\dot{\gamma}_v\dot{\gamma}_2$	$[R]_s/[R]_{2\ max}$	$I/\hat{I}$	$\dot{\gamma}_v\dot{\gamma}_2$	$[R]_s/[R]_{2\ max}$
0.01	0.0035	3.3	0.06	0.058	0.01	0.2	0.051
0.02	0.019	1.9	0.242	0.079	0.02	0.46	0.045
0.04	0.06	1.45	0.72	0.084	0.04	1.045	0.038
0.07	0.12	1.15	1.07	0.112	0.07	1.23	0.057
0.10	0.18	1.0	1.275	0.141	0.10	1.275	0.079
0.20	0.33	0.85	1.3	0.254	0.20	1.10	0.182
0.40	0.58	0.70	1.40	0.414	0.40	0.98	0.41
0.70	0.82	0.56	1.43	0.573	0.70	0.80	0.875
1.00	1.00	0.50	1.30	0.77	1.00	0.65	1.54

*Transfer characteristic similar to iconoscope for $E_1 \simeq 4$, Fig. II, Part I.

Table XXI. Relative Signal-to-Deviation Ratios $[R]_s/[R]_{max}$ for Vidicon ($\gamma_1 = 0.6$) and Light-Spot Scanner ($\gamma_1 = 1$).

	Vidicon, $\gamma_1 = 0.6$			Light-spot scanner, $\gamma_1 = 1$			
$E_1/\hat{E}_1$	$I/\hat{I}$	$\dot{\gamma}_v\dot{\gamma}_2$	$[R]_s/[R]_{2\ max}$	$I/\hat{I}$	$(I/\hat{I})^{\frac{1}{2}}$	$\dot{\gamma}_v\dot{\gamma}_2$	$[R]_s/[R]_{0\ max}$
0.01	0.064	0.33	0.194	0.01	0.10	0.20	0.51
0.02	0.097	0.77	0.126	0.02	0.141	0.46	0.308
0.04	0.148	1.74	0.085	0.04	0.20	1.045	0.191
0.07	0.205	2.05	0.10	0.07	0.264	1.23	0.215
0.10	0.255	2.12	0.12	0.10	0.316	1.275	0.248
0.20	0.385	1.84	0.21	0.20	0.447	1.10	0.406
0.40	0.57	1.64	0.348	0.40	0.631	0.98	0.645
0.70	0.80	1.34	0.596	0.70	0.835	0.80	1.045
1.00	1.00	1.08	0.93	1.00	1.00	0.65	1.54

the most pleasing transfer characteristics are s-shaped as shown by Fig. 102 with a center-range gamma in the order of 1.2. The transfer characteristics obtained with linear amplifiers ($\gamma_v = 1$) from *iconoscopes used for motion-picture film pickup* or from *image orthicons* (studio pickups) are similar to that of a motion-picture process and will therefore be used as a representative standard.† For comparison the amplifier gamma ($\dot{\gamma}_v$) for all other camera-tube types will be adjusted to result in a system gamma (γ_T) and a transfer characteristic equal to curve 1 in Fig. 102.

Because the video amplifier is linear ($\gamma_v = 1$), the relative-signal voltage $E/\hat{E}$ at the kinescope grid is directly equal to the relative-signal current $I/\hat{I}$ from the camera tube. Corresponding values of screen luminance $B/\hat{B}$ and $\dot{\gamma}_2$ for the signals $E/\hat{E} = I/\hat{I}$ obtained from a representative kinescope characteristic (Fig. 21, Part I) are listed in columns 3 and 4 of Table XIX. The relative signal-to-deviation ratio $[R]_s/[R]_{1\ max}$ computed with Eq. (85a) for $\alpha\beta = 1$, $\gamma_v = 1$ and $\dot{\gamma}_b = \dot{\gamma}_2$ is tabulated in column 5, and shown by curve 1 in Fig. 103. Columns 6 and 7 of Table XIX list the point-gamma values of the image orthicon (Fig. 7, Part I) and the point gamma ($\dot{\gamma}_T$) of the overall system characteristic curve 1 in Fig. 102.

The signal-to-deviation characteristic for an *image-iconoscope* camera chain giving an identical overall transfer characteristic is readily computed by tabulating its signal-current ratio $I/\hat{I}$ and $\dot{\gamma}_1$ for the same relative exposure values $E_1/\hat{E}_1$ as listed in Table XX. The product $\dot{\gamma}_v\dot{\gamma}_2 = \gamma_T/\gamma_1$ is then computed for the desired values $\dot{\gamma}_T$ of Table XIX. The corresponding signal-to-deviation ratios are shown as curve 3 in Fig. 103. Table XX also lists the values obtained similarly for an *orthicon* or a *linear vidicon* camera ($\gamma_1 = 1$). The relative signal-to-deviation ratios for a *vidicon with low constant gamma* ($\gamma_1 = 0.6$) and *a light-spot scanner* ($\gamma_1 = 1$) are given in Table XXI. The values for the light-spot scanner phototube signals require calculation of $(I/\hat{I})^{\frac{1}{2}}$ because of Eq. (84). The preferred characteristic for camera tubes (curves 1 to 5 in Fig. 103) is that of the image orthicon and iconoscope (curves 1 and 2) which is a close approach to the characteristic obtained from a theoretical constant-gamma system with a camera-tube gamma $\gamma_1 = 0.6$. The previous conclusion that a $\gamma_1 = 0.6$ is optimum does, therefore, not apply to a system with variable gamma as seen by comparison of curve 5 of Fig. 103 with curve 0.6 of Fig. 101.

† A different reference characteristic would not change relative performance values between television-camera tubes.

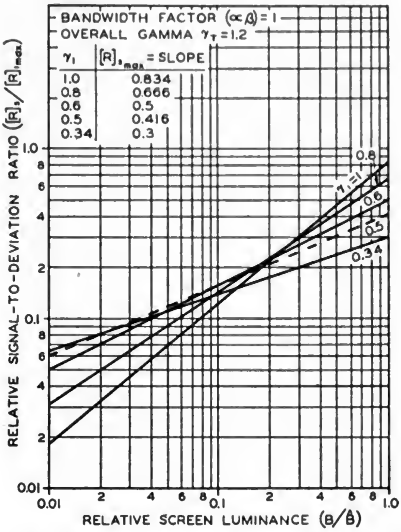


Fig. 101. Relative signal-to-deviation ratio of television systems having the same constant overall gamma and constant "flat" channel noise-level, but camera tubes with different constant gamma values.

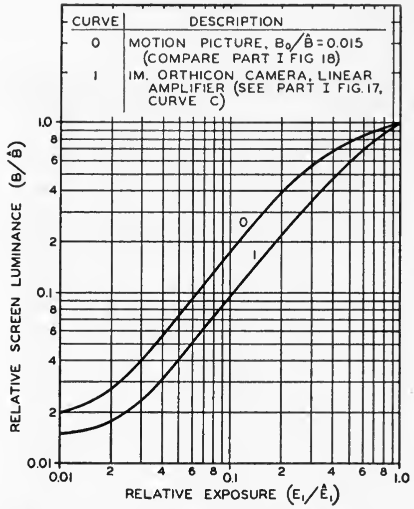


Fig. 102. Transfer characteristics of motion-picture and television processes.

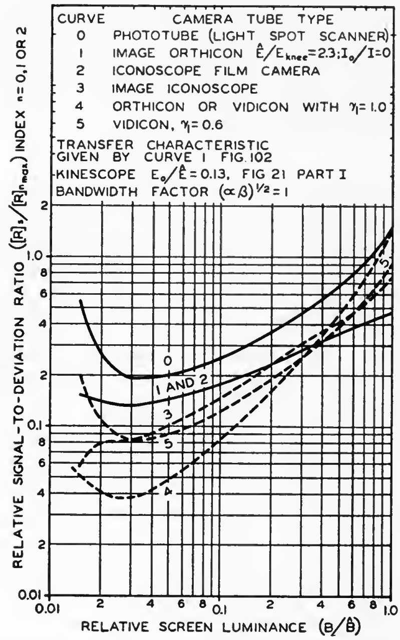


Fig. 103. Relative signal-to-deviation ratios of television systems using various camera-tube types having equal signal-to-noise ratios $[R]_m$ at the source and gamma correction to obtain the transfer characteristic 1, Fig. 102.

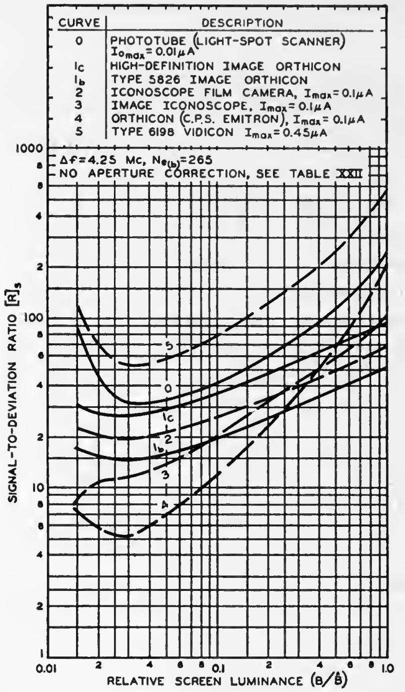


Fig. 104a. Signal-to-deviation ratios at the screen of standard 525-line USA television systems using an average kinescope ($N_{e(b)} = 265$), no aperture correction, but gamma correction to obtain the transfer characteristic 1, Fig. 102.

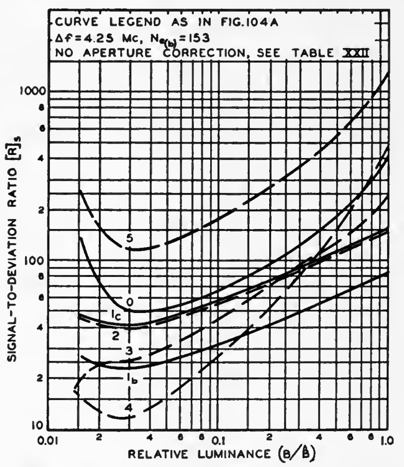


Fig. 104b. Signal-to-deviation ratios in the retinal image for the conditions of Fig. 104a modified by a viewing distance $d = 4V$, which changes $N_{e(b)}$ to 153.

2. Signal-to-Deviation Characteristics of Image Frames on the Kinescope Screen and at the Retina of the Eye

The signal-to-deviation characteristics in Fig. 103 are relative characteristics computed for identical transfer characteristics (curve 1, Fig. 102), identical signal-to-noise ratios at the source, and bandwidth factors $(\alpha\beta)^{\frac{1}{2}} = 1$. A numerical comparison of image granularity requires adjustment of the $[R]_s$-scale according to actually obtained signal-to-noise ratios $[R]_m$ and bandwidth factors $(\alpha\beta)^{\frac{1}{2}}$ for representative electrical systems and succeeding optical apertures $(N_{e(b)})$. The characteristics $[R]_s = f(B/\hat{B})$ are obtained according to Eqs. (84) and (85) by multiplication of the relative characteristics in Fig. 103 with appropriate scale factors $[R]_{m\ \max}/(\alpha\beta)^{\frac{1}{2}}$. Electrical aperture correction and variation of the optical aperture passband $N_{e(b)}$ have a considerable effect on the numerical values $[R]_s$, which differ substantially for flat- and peaked-channel noise sources. The relative magnitude and appearance of deviations in the retinal image vary with viewing distance and can be computed by including the aperture process of the eye in the value $N_{e(b)}$ as shown in the following examples.

Without aperture correction ($r_{\bar{z}c} = 1$ *at* N_c) the factors $m^{\frac{1}{2}}$ and $\alpha^{\frac{1}{2}}$ of the system are determined by the type of noise source (flat or peaked), the cutoff filter, and the equivalent passband $N_{e(b)}$ of the optical apertures following the point of noise insertion, while $\beta^{\frac{1}{2}}$ is determined by n_r and $N_{e(b)}$ only. The values computed for a standard (U.S.A.) monochrome television channel and a typical kinescope are given in Table XXII and Figs. 104a and 104b. When the passband $N_{e(b)}$ of the optical-system apertures is changed, the $[R]_s$-characteristics for all camera chains with flat-channel noise sources are shifted as a group with respect to the group of $[R]_s$-characteristics for camera chains with peaked-channel noise sources because the difference in the horizontal frequency spectra causes $\alpha^{\frac{1}{2}}$ to change by different factors (see Figs. 99 to 100). *The visual appearance of grain structures* depends on the granularity of the retinal image which can be computed as follows. For direct-viewing conditions the equivalent passband $N_{e(b)}$ is the cascaded value for the kinescope (N_{e2}) and the eye $(N_{e(eye)})$, which varies as a function of viewing distance, and may be obtained for an average field luminance of 4 to 10 ft-L from:

$$N_{e(eye)} = 752\ (V/d) \qquad (87)$$

The characteristics in Fig. 104a represent, therefore, a close viewing distance where $N_{e(b)}$ is substantially equal to the equivalent passband of the kinescope: $N_{e(b)} \simeq N_{e2} = 265$. An increase of the viewing ratio to $d/V = 4$ changes $N_{e(eye)}$ to 188 and the cascaded value (Eq. (30b), Part II) of kinescope and eye to $N_{e(b)} = 153$, resulting in the characteristics given in Fig. 104b. Before conclusions can be drawn, it is advisable to consider the effects of aperture correction.

Aperture correction ($r_{\bar{z}c} > 1$ *at* N_c) is used to increase the high-frequency sine-wave signals from the camera tube in order to obtain better definition. The magnitude of the correction depends on the response of the camera tube and varies, therefore, for different tube types. A change of the high-frequency response of the video amplifier, however, alters its relative passband and the bandwidth factors m and α. A proper comparison of $[R]_s$-characteristics from different camera tubes should therefore be based on the additional condition that the horizontal sine-wave response $r_{\psi 1} r_{\bar{z}}$ of camera tube, aperture-correcting circuit, and electrical filter is adjusted to be substantially alike. The correction required for each case can be determined as follows. Assume that it is desired to obtain a response $r_{\psi 1} r_e$ equal to that of the sharp-cutoff filter shown in Fig. 82. This filter has a factor $m^{\frac{1}{2}} = 0.975$. It is only necessary to determine the bandwidth factor $\alpha_1 = (N_{e1}/N_c)_h$ of the camera tube, locate it

Table XXII. Maximum Signal-to-Deviation Ratios $[R]_{s\ max}$ of 525-line Television System With $\Delta f = 4.25$ Mc, Transfer Characteristic Curve 1, Fig. 103, No Aperture Correction ($r_{\tilde{e}_c} = 1$ at N_c).

Curve No.	Type of signal source	$[R]_{m\ max}$	$m^{\frac{1}{2}}$	$\dot{\gamma}_v$	$[R]_{3\ max}$	$N_{e(b)} = 265$ (Kinescope) $\beta^{\frac{1}{2}}$	$\alpha^{\frac{1}{2}}$	$\dot{\gamma}_s$	$[R]_{s\ max}$	$\bar{N}_{e(s)}$	$N_{e(b)} = 153$ (Kine. + eye for $d/V = 4$) $\beta^{\frac{1}{2}}$	$\alpha^{\frac{1}{2}}$	$[R]_{s\ max}$	$\bar{N}_{e(s)}$
0	Light-spot scanner, $I_{max} \simeq 0.01\mu$	100	0.98	0.31	330	0.735	0.825	0.65	254	247	0.56	0.665	414	152
1a	Image orthicon, 5820	34	0.98	1.0	37.7	0.735	0.825	2.1	26.8	247	0.56	0.665	43.5	152
1b	Image orthicon, 5826	66	0.98	1.0	67.4	0.735	0.825	2.1	52	247	0.56	0.665	84.5	152
1c	Image orthicon, high-definition	120	0.98	1.0	122.5	0.735	0.825	2.1	94.6	247	0.56	0.665	153.5	152
2	Iconoscope (film pick-up), $I_{max} = 0.1\ \mu a$	70	0.914	1.0	76.5	0.735	0.66	2.1	69.0	201	0.56	0.4	149	91.6
3	Im. iconoscope, $I_{max} = 0.1\ \mu a$	70	0.914	0.62	123.5	0.735	0.66	1.3	111.0	201	0.56	0.4	240	91.6
4	Orthicon [C.P.S. Emitron), $I_{max} = 0.1\ \mu a$	70	0.914	0.31	247	0.735	0.66	0.65	222	201	0.56	0.4	482	91.6
5	Vidicon, 6198, $I_{max} = 0.45\ \mu a$	315	0.914	0.515	668	0.735	0.66	1.08	600	201	0.56	0.4	1300	91.6
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(5)	(6)	(8)	(9)

Notes:
(1) From Table XVII.
(2) From Table XVII sharp filter, aperture correction 1 ×.
(3) $\dot{\gamma}_v = \dot{\gamma}_v\dot{\gamma}_2/2.1$ value at $\hat{B}$ from Tables XIX to XXII.
(4) Signal-to-noise ratio after filter, Eq. (80).
(5) Eq. (81) for $n_r = 490$.
(6) From Figs. 99a or 100a for $N_{c(h)} = 340$, curve 1.
(7) From Tables XIX to XXII at $\hat{B}$.
(8) Eq. (69).
(9) Eq. (68).

Table XXIII. Maximum Signal-to-Deviation Ratios $[R]_{s\,max}$ of 525-line Television System With $\Delta f = 4.25$ Mc, Transfer Characteristic Curve 1, Fig. 103, and Maximum Aperture Correction.

Curve no.	Type of signal curve	$[R]_{m\,max}$	N_{el}	Apt. corr. at N_c	$N_{e(b)} = 265$: $\alpha^{\frac{1}{2}}$	$\beta^{\frac{1}{2}}$	$\dot{\gamma}_s$	$[R]_{s\,max}$	$\bar{N}_{e(s)}$	$N_{e(b)} = 153$ (Kine. + eye for $d/V = 4$): $\alpha^{\frac{1}{2}}$	$\beta^{\frac{1}{2}}$	$[R]_{s\,max}$	$\bar{N}_{e(s)}$
0	Light spot scanner, $I_{max} = 0.01\ \mu a$	100	250	2	1.0	0.735	0.65	210	300	0.74	0.56	372	169
1a	Image orthicon, 5820	34	200	2.5	1.12	0.735	2.1	19.7	336	0.79	0.56	37	180
1b	Image orthicon, 5826	66	200	2.5	1.12	0.735	2.1	38.2	336	0.79	0.56	71	180
1c	Image orthicon, high-definition	120	250	2	1.0	0.735	2.1	78	300	0.74	0.56	138	170
2	Iconoscope (film pickup), $I_{max} = 0.01\ \mu a$	70	200	2.5	1.15	0.735	2.1	39	346	0.61	0.56	98	140
3	Image iconoscope, $I_{max} = 0.1\ \mu a$	70	200	2.5	1.15	0.735	1.3	64	346	0.61	0.56	158	140
4	Orthicon (C.P.S. emitron), $I_{max} = 0.1\ \mu a$	70	200	2.5	1.15	0.735	0.65	127	346	0.61	0.56	315	140
5	Vidicon, 6198, $I_{max} = 0.45\ \mu a$	315	158	4	1.66	0.735	1.08	239	500	0.84	0.56	620	192
		(1)	(2)	(3)	(4)		(5)	(6)	(7)	(4)		(6)	(7)

Notes:
(1) From Table XXII.
(2) Equivalent passband of camera tubes (approximate values).
(3) Obtained from Fig. 99a for $(N_{e(\psi)}/N_e)_h = N_{el}/340$ and $\alpha^{\frac{1}{2}} = 0.975$ (to obtain $r_{\psi 1} r_{\bar{z}} = r_{\bar{z}f}$).
(4) From Fig. 99a or 100a for $N_{e(h)} = 340$ and $N_{e(\psi)} = N_{e(b)}$.
(5) From Table XXII, value at $\hat{B}$.
(6) Eq. (69).
(7) Eq. (68).

Table XXIV. Maximum Signal-to-Deviation Ratios $[R]_{s\ \max}$ of 625-line Theater Television System With $\Delta f = 8$ Mc, Transfer Characteristic Curve 1, Fig. 103, and Maximum Aperture Correction.

Curve no.	Type of signal source	$[R]_{m\ \max}$	Apt. corr. at N_c	$m^{\frac{1}{2}}$	$\dot{\gamma}_v$	$[R]_{3\ \max}$	$N_{e(b)} = 400$, (at screen) $\alpha^{\frac{1}{2}}$	$\beta^{\frac{1}{2}}$	$\dot{\gamma}_v$	$[R]_{s\ \max}$	$\bar{N}_{e(s)}$	$N_{e(b)} = 240$, $(d/V = 2.5)$ $\alpha^{\frac{1}{2}}$	$\beta^{\frac{1}{2}}$	$[R]_{s\ \max}$	$\bar{N}_{e(s)}$
0	Light-spot scanner, $I_{\max} \simeq 0.01\ \mu$	73	4	2.02	0.31	116.5	1.43	0.83	0.65	94.7	665	0.94	0.642	186	338
1b	Image orthicon, 5826	48.1	6	2.76	1.0	17.4	1.9	0.83	2.1	14.5	884	1.18	0.642	30	425
1c	Image orthicon, high-definition	87.5	4	2.02	1.0	43.3	1.43	0.83	2.1	35.1	665	0.94	0.642	69	338
3	Image iconoscope, $I_{\max} = 0.1\ \mu a$	27.1	6	3.57	0.62	12.2	2.26	0.83	1.3	11.1	1050	1.08	0.642	30	388
4	Orthicon (C.P.S. emitron), $I_{\max} = 0.1\ \mu a$	27.1	6	3.57	0.31	24.5	2.26	0.83	0.65	22.2	1050	1.08	0.642	60	388
5	Vidicon, 6198, $I_{\max} = 0.45\ \mu a$	122	6	3.57	0.515	66.5	2.26	0.83	1.08	60.2	1050	1.08	0.642	163	388
		(1)	(2)		(3)	(4)	(5)	(6)	(3)		(7)	(5)	(6)		(7)

Notes:

(1) Values from Table XXII multiplied by $(4.25/8)^{\frac{1}{2}}$ for curves 0, 1b and 1c; and by $(4.25/8)^{\frac{3}{2}}$ for curves 3, 4 and 5.
(2) Curves 0 and 1c corrected to $\alpha^{\frac{1}{2}} = 0.975$; curves 1b, 3 and 4 corrected to $\alpha^{\frac{1}{2}} = 0.95$; curves 3, 4 and 5 corrected to $\alpha^{\frac{1}{2}} = 0.71$
(3) From Table XXII.
(4) Electrical signal-to-noise ratio after filter, Eq. (80).
(5) From Figure 99a or 100a for $N_{c(h)} = 537$.
(6) Eq. (81) for $n_r = 584$.
(7) Eq. (68) for $(N_{c(h)} n_r)^{\frac{1}{2}} = 560$.

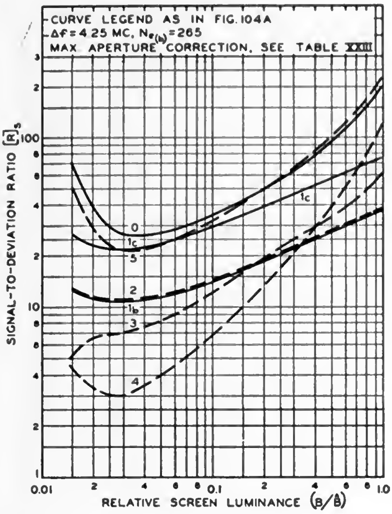


Fig. 105a. Signal-to-deviation ratios at the screen of standard 525-line USA television systems using an average kinescope ($N_{e(b)}$ = 265), aperture correction for equal horizontal sine-wave response, and gamma correction to obtain the transfer characteristic 1, Fig. 102.

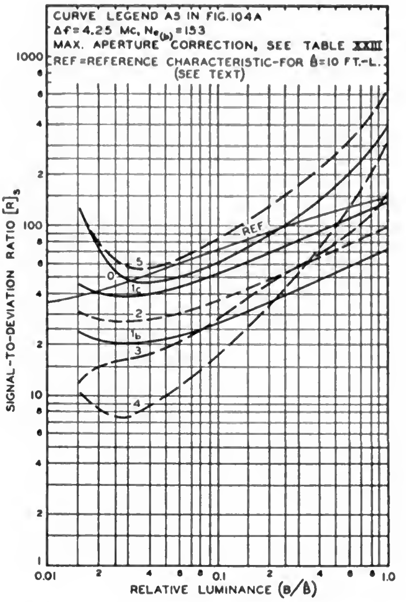


Fig. 105b. Signal-to-deviation ratios in the retinal image for the conditions of Fig. 105a modified by a viewing distance $d = 4V$.

on the abscissa of Fig. 99a and read off the aperture correction required for the desired value $\alpha^{\frac{1}{2}} = m^{\frac{1}{2}} = 0.975$. A tabulation of the values obtained for a standard television channel ($N_{c(h)}$ = 340) is given in column 3 of Table XXIII. The various degrees of aperture correction alter the factors $\alpha^{\frac{1}{2}}$ of the system following the point of "noise" insertion as listed in column 4 for the previously used apertures $N_{e(b)} = 265$ and $N_{e(b)} = 153$ following the electrical system. The corresponding $[R]_s$-characteristics shown in Figs. 105a and 105b are based on equal transfer characteristics and equal horizontal response in a standard television channel with n_r = 490 and $N_{c(h)} = 340$.

A comparison of the signal-to-deviation characteristics of a standard 35mm motion-picture projection (Fig. 57b, Part II) and television images of similar quality is given in Table XXIV and Figs. 106a, 106b, and 106c. It will be shown in Part IV that a 30-frame television system having n_s = 625 lines and a video passband Δf = 8 mc is adequate to duplicate 35mm motion-picture performance. This performance can be obtained only with high-quality signal sources, maximum aperture correction and high-quality reproducers (N_{e2} = 400). The performance of all camera-tube types, however, has been computed for comparison. The $[R]_s$-characteristics Fig. 106a represent conditions at the screen and Figs. 106b and 106c at the retina of the eye for the viewing distances $d = 2.5V$ and $4V$ respectively. The motion-picture characteristic in Fig. 106a is the $[R]_p$-characteristic shown in Fig. 57b of Part II. At a viewing distance $d = 2.5V$ the equivalent passband of the eye is $N_{e(eye)} = 300$ (Eq. (87)). In cascade with the equivalent passband $N_{e(p)} = 370$ of the motion picture, the overall system passband be-

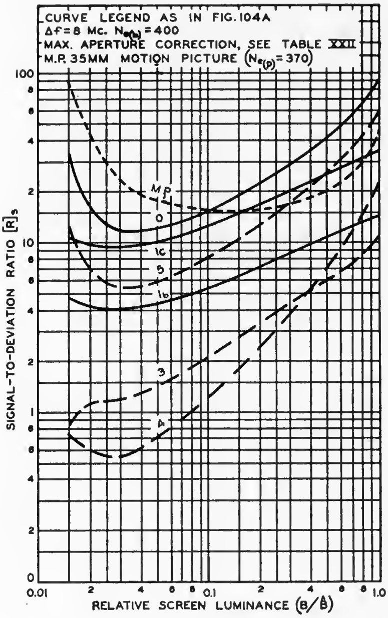


Fig. 106a. Signal-to-deviation ratios at the screens of 35mm motion-picture and 625-line theater-television systems (Δf = 8 mc) having the transfer characteristics in Fig. 102, a television projector with $\bar{N}_{e(b)}$ = 400 and high aperture correction to provide equivalent sharpness (see text).

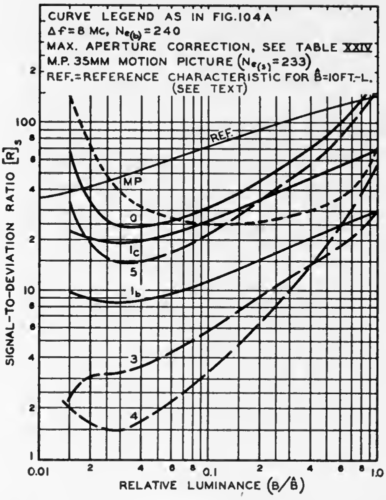


Fig. 106b. Signal-to-deviation ratios in the retinal image for the conditions of Fig. 106a modified by a viewing distance $d = 2.5V$.

comes $\bar{N}_{e(s)}$ = 233. The motion-picture characteristic in Fig. 106b is obtained with $[R]_s = [R]_p$ (370/233) and in Fig. 106c with $[R]_s = [R]_p$ (370/188) because in these cases the relative amplitude distribution in the deviation spectrum and the products $[R]_p\bar{N}_{e(s)}$ remain substantially constant (see p. 22, Part II). The characteristics in Fig. 106 show that in the medium and light tone range the motion-picture frames have larger deviations (lower $[R]_s$) than the television systems curves 0, 1c and 5, but that the granularity of the motion picture is lower in the shadow tones.

With increasing viewing distance, the signal-to-deviation characteristic of the aperture-corrected television systems im-

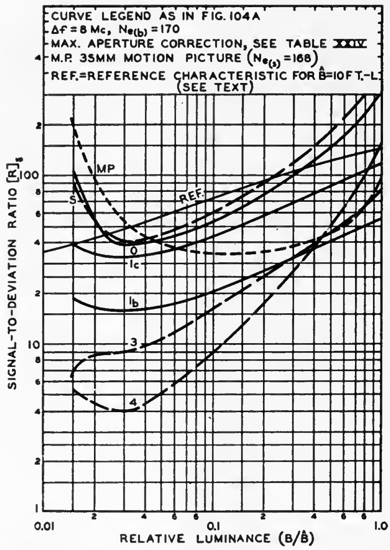


Fig. 106c. Signal-to-deviation ratios in the retinal image for the conditions of Fig. 106a modified by a viewing distance $d = 4V$.

proves more rapidly than that of the motion picture. It must also be borne in mind that the signal-to-deviation ratios evaluated for the motion picture are values that neglect all defects and scratches which noticeably increase the deviation level in the film projection above the ideal values after relatively few runs, as borne out by measurements of the noise level from the sound track of motion-picture film. There is no parallel degradation in live-television systems, because every showing is a "first" showing. The signal-to-deviation characteristics of the theater-television systems using the high-definition image orthicon (Fig. 95), light-spot scanners, or the type-6198 vidicon are, therefore, satisfactory in comparison with motion pictures. The definition obtained with the type-6198 vidicon, however, is not equivalent to 35mm motion pictures.

3. Equivalent Passband ($\bar{N}_{e(s)}$) and Sine-Wave Amplitudes

Amplitude distribution and N_e-values for the sine-wave spectrum of the deviations in a television frame can be computed accurately from the products of corresponding response factors for the system elements following the noise source.

The sine-wave response of a particular combination of elements can be approximated with good accuracy by one of the normalized characteristics given in this paper. The analysis of the intensity distribution in the vertical coordinate (Eq. (57) and Fig. 70) has shown that the television raster may produce a carrier wave containing a series of sine-wave components with fixed amplitudes. These constant carrier components are not included in the total energy of the deviations. When the deviations originate in electrical elements, the vertical-frequency spectrum is in all cases that of the aperture δ_b following the electrical elements (see section C2). The sine-wave response of theater-television systems (not including camera) is illustrated in Fig. 107. The response factors are by definition the amplitudes obtained with a normalized sine-wave energy input into the theoretical television channel, i.e., for an rms noise input voltage $[\tilde{E}]_m = 1$. The equivalent passbands in the horizontal and vertical coordinates have been related to the theoretical passband by bandwidth factors; $N_{e(h)} = \alpha N_c$ and $N_{e(v)} = \beta n_r$ to permit evaluation by normalized characteristics. The equivalent passband ($\bar{N}_{e(s)}$) of the system is computed with Eq. (68) (see Tables XXII to XXIV).† While the response factors in the horizontal and vertical coordinates are independent of one another, the actual amplitudes of the sine-wave flux components of the deviation flux are not, because the total sine-wave deviation energy $P_0 = c^2\bar{N}_e$ is independent of direction. For a normalized deviation "output" energy $P_0 = 1$, the amplitude scale factor is therefore $c = \bar{N}_e^{-\frac{1}{2}}$ for symmetrical apertures, and the amplitude distribution $Y_{(N)} = f(N)$ is obtained by multiplying the response factors r_ψ by the scale factor:

$$Y_{(N)} = r_\psi c = r_\psi(\bar{N}_e)^{-\frac{1}{2}} \qquad (89)$$

Similarly for television systems:

$$\left.\begin{aligned} Y_{(N)h} &= r_{\psi(h)} \qquad c_{(h)} = r_{\psi(h)}(\alpha N_c)^{-\frac{1}{2}} \\ &\text{and} \\ Y_{(N)v} &= r_{\psi(v)}c_{(v)} = r_{\psi(r)}(\beta n_r)^{-\frac{1}{2}} \end{aligned}\right\} \qquad (90)$$

The *relative* amplitude characteristics corresponding to Fig. 107 are shown in Fig. 108. The characteristic of the 35mm

---

† Because of aperture correction the value $\bar{N}_{e(s)}$ does exceed the theoretical value $\bar{N}_{e(m)}$ considerably for the condition $N_{e(b)} = 400$ in Table XXIV. This abnormal condition exists for deviations only and it should be remembered that an equivalent passband is by definition a "flat" passband which would contain the same total deviation energy. The system response to sine-wave components in picture signals is normal, because it includes the decreasing response of the camera tube.

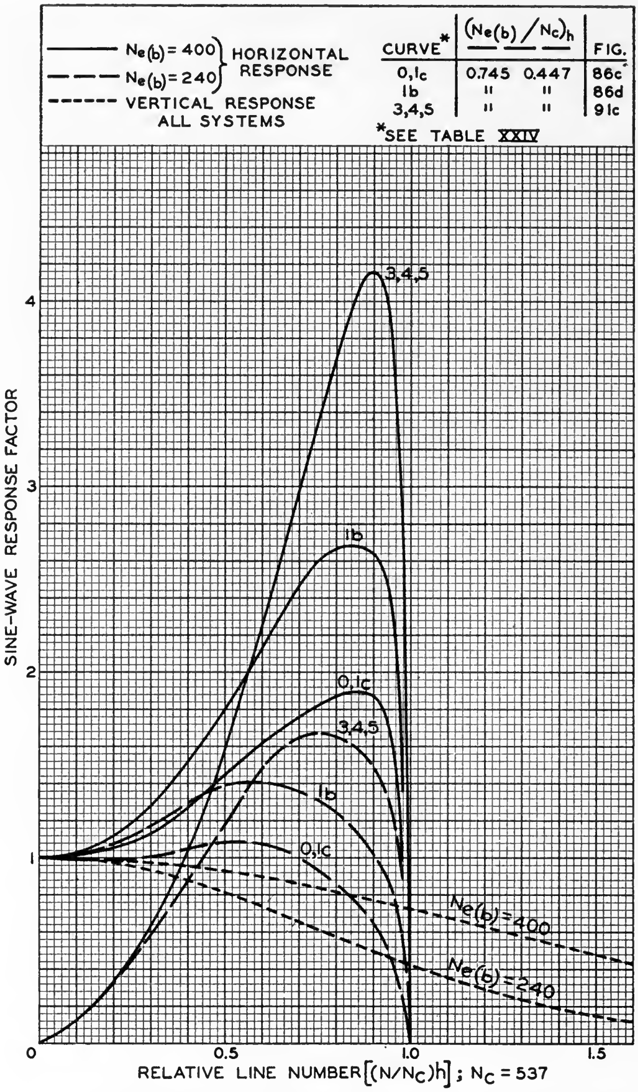


Fig. 107. Sine-wave response factors of theater-television and motion-picture systems for the conditions of Figs. 106a and 106b.

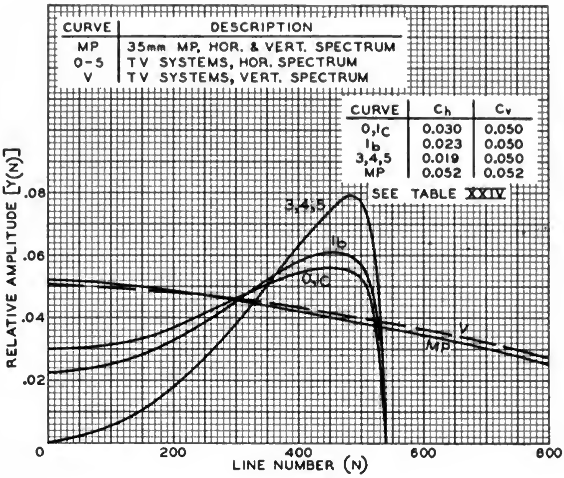


Fig. 108a. Relative amplitudes of sine-wave spectra for equal-energy signals and deviations at the screen of theater-television and motion-picture systems.

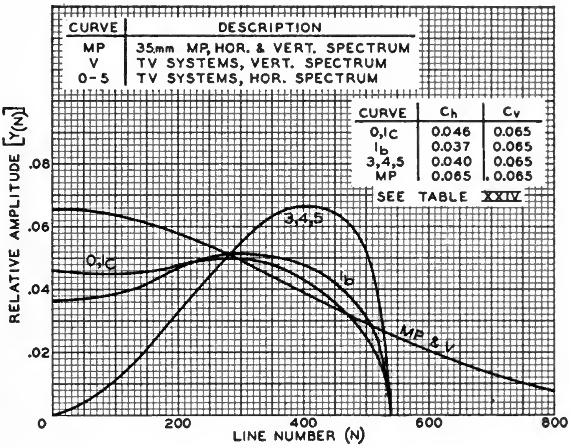


Fig. 108b. Relative amplitudes of sine-wave spectra for equal-energy signals and deviations at a viewing distance $d = 2.5V$ from the screen of theater-television and motion-picture systems.

motion picture in Fig. 108a is that of Fig. 59, Part II, normalized for $P_0 = 1$ by multiplication with $c = 370^{-\frac{1}{2}} = 0.0518$, and by $c = 233^{-\frac{1}{2}} = 0.0653$ for Fig. 108b, which represents conditions at the retina for a viewing distance $d = 2.5V$.

The visual appearance of the grain structures in motion-picture and television frames is indicated by the amplitude spectra (Fig. 108) for equal signal-to-deviation ratios. The vertical spectra are substantially identical and the preponderance of low frequencies indicates a soft grain structure. The horizontal television spectra for "flat" channel deviations (0, 1*b*, 1*c*) have a somewhat smaller and sharper appearing grain size. The "peaked" channel deviations (3, 4, 5) containing no low frequencies and having maximum energy at a fairly high line number (N = 400 to 500), have a smaller and more uniform appearing grain size.

This interpretation of the amplitude spectra may be compared with the grain

Figure 109 is on plate pages 118 and 119.

structure photographs shown in Fig. 109 which were taken under somewhat similar conditions in a 4.5-mc system for the purpose of measuring the deviation ratio in an image frame by sampling with a physical aperture. The linear dimension of the samples in Fig. 109 is approximately one-fourteenth of a picture frame. The samples A, B and C are photographs of "peaked" channel, "flat" channel, and 35mm motion-picture grain structures respectively. In the top row (index 1) are single-frame grain structures obtained with small apertures δ_b showing the raster line structure of the television samples A and B. The middle row (2) illustrates the condition for a larger aperture δ_b for all 3 cases. This aperture was given a value to produce a "flat field" in the television frames and equal the spot size of the supercinephor lens for C2. Note the longer grain size in the vertical direction of A2 which is evidence of the flat-frequency spectrum across the raster even from a peaked "noise" source, which causes positive- and negative-grain doublets in the horizontal coordinate due to the absence of low frequencies and the differentiated pulse shape shown in Fig. 93. The samples A3 and B3 show the effect of superimposing the grain structures of six television frames by a photographic exposure of $\frac{1}{5}$ sec. The deviations were increased in magnitude to show more clearly that the grain doublets have practically disappeared in A3 due to random superposition.

4. Discussion of Results

Examination of the various signal-to-deviation characteristics shows clearly that the theoretical signal-to-noise ratios $[R]_{m\ \max}$ (Table XVII) is not an adequate measure of camera-tube performance. It is evident from Tables XXII and XXIII that the electrical signal-to-noise ratios $[R]_{3\ \max}$ which can be measured in the video-transmission link, may also differ substantially from the theoretical value $[R]_{m\ \max}$, because for comparable definition the sine-wave response of the camera tube is reflected in the degree of aperture correction and alters the sine-wave amplitudes in the frequency spectrum of the deviations.

Aperture correction increases the noise level by a factor which is larger for peaked-channel noise than for flat-channel noise, as illustrated by the value of the electrical factor $m^{\frac{1}{2}}$ in Table XXIV for conditions 1b and 3, for example. The filtering action of succeeding apertures has an opposite effect, reducing the deviation level $(1/[R]_s)$ and granularity of the retinal image by a larger factor for peaked-channel noise than for flat-channel noise. These factors are given by the ratio of corresponding factors $\alpha^{\frac{1}{2}}$ which, according to Table XXII, is $0.665/0.4 = 1.66$ in favor of peaked-channel noise without aperture correction and at a viewing distance $d = 4V$ from a standard 525-line television image.† When moderate aperture correction is used the ratio decreases (see Table XXIII) and with high aperture correction it approaches unity (see Table XXIV) and may even reverse. *It therefore appears desirable to specify the entire signal-to-deviation characteristic in the retinal image for a given viewing distance.* To judge the entire characteristic it is necessary to establish a *reference characteristic based on the perception of random deviations* as a function of luminance.

Subjective observations as well as fun-

† This value is considerably lower than the ratio given in the author's earlier paper.[3] The earlier values are in error because they are ratios of bandwidth factors (α) rather than factors ($\alpha^{\frac{1}{2}}$).

damental considerations[6,7] indicate that the visual perception of fine detail and granularity is limited at low luminance values by random fluctuations in the visual process and at medium and high luminance values by the aperture response of the optical system of the eye (see, for example, Fig. 83). From an objective point of view, perception of fluctuations from an external source (image) in the low luminance range occurs when the total deviation from both external and internal sources exceeds the internal deviations of the visual process by a barely perceptible amount which can be assumed related to a visual sensation unit. When the optical and photoelectric characteristics of the eye are known, the ratio of the two deviations may be calculated as a function of luminance by the method outlined in this paper. The evaluation of an analog system for the visual process based on data from subjective observations appears possible and of considerable value for an objective analysis. This will be discussed in Part IV.

For the present it is sufficient to refer to such observations, which indicate that the signal-to-deviation ratio in an external or retinal image required to give threshold visibility, is nearly constant for luminance values (B) above 10 ft-L, and decreases for values less than 10 ft-L. The luminance values of motion-picture and theater-television projections fall into this lower range. For use as a reference standard the exact vertical location of the threshold curve for the eye is not important, unless one is specifically interested in threshold values.† Shape and approximate location of the reference characteristic are shown in Figs. 106b and 106c, for a highlight brightness $\hat{B}$ = 10 ft-L. It is noted that the image-orthicon curves 1b and 1c have a fairly uniform vertical distance to the reference characteristic, which means that perception of their grain structure is fairly uniform, decreasing towards the ends of the range. The shape of the motion-picture characteristic (MP) indicates that its grain structure will appear most perceptible at $B/\hat{B} \simeq 0.4$ but is invisible in the deep shadow tones.

Referring now particularly to Fig. 106b which represents conditions at the close viewing distance of 2.5 times the vertical screen dimension, it can be seen that graininess in the systems represented by curves 5 and MP will be perceived with similar intensities but in a different part of the luminance range. Similarly, when comparing curves 1_c and MP, and it is evident that the motion picture will appear more grainy in the upper half of the tone range than the television picture which exhibits a nearly uniform graininess over the entire range. At the more normal viewing distance of $d = 4V$ represented by Fig. 106c, the characteristic of the motion picture is positioned for the most part much farther below the threshold-reference characteristic than those of the television systems 0, 5 and 1*c*, which now appear in general less grainy than the motion picture. Considering furthermore that the motion-picture characteristic is representative of an ideally "clean" film it can be concluded that the graininess of theater-television images, such as are represented by curves 0, 1*c* and 5 in particular, will compare favorably with that of 35mm motion pictures.

The evaluation of deviations of electrical origin in television frames has shown that television systems may be designed to have a performance substantially equal to a 35mm motion-picture system. Because of the similar frame rate, the storage factor s and signal-to-fluctuation ratios in "live" television pictures are not materially different from those of motion pictures.

† It is noted that observations on the perception of fluctuations in television pictures made at luminance values above 10 ft-L are not likely to apply directly to the lower luminance values of theater television and motion pictures.

A camera tube with adequate signal output and definition such as the experimental high-definition image orthicon (curve 1*c* in Fig. 106, and Table XXII is required for a theater-television system having a granularity comparable to that of a 35mm motion picture using plus X) negative and fine-grain positive film (1302). The theoretical value $[R]_{m\ max}$ at the source for this type of camera tube corresponds to an electrical noise level of −38.8 db, or −41.3 db including synchronizing signals. The noise level in the video-transmission system (corresponding to $[R]_3 = 43.4$) is −32.7 db, or −35.2 db including synchronizing signals. To prevent impairment of this performance, the noise level of the transmission system itself should be approximately 6 db better, or both the transmission system and the camera tube should have noise levels 3 db lower than stated above.

A more accurate statement can be made when the amplitude distribution in the frequency spectrum of the additive noise is known. Statistical tests of signal-to-deviation ratios by the sampling of television grain-structure photographs on 4 × 5-in. film have been in good agreement with computed values. The above method has also been applied to compute the noise levels reported by Pierre Mertz in two publications.[8,9] In view of the estimates which had to be made for a number of unspecified system constants the calculated values appeared to be in satisfactory agreement with the reported values.

Many relations between apertures and their sine-wave response characteristics as well as characteristics of vision have only been indicated and will be discussed in more detail in Part IV of this paper.

References

1. Pierre Mertz and T. Gray, "The theory of scanning and its relation to the characteristics of the transmitting signal in telephotography and Television," *Bell Sys. Tech. J., 13:* p. 464, 1934.
2. I. C. Gardner, "A new resolving power test chart," (abstract), *J. Opt. Soc. Am., 40:* 257, Apr. 1950.
3. O. H. Schade, "Electro-optical characteristics of television systems, Part III—Electro-optical characteristics of camera systems," *RCA Rev., 9:* 490–530, Sept. 1948.
4. P. Schagen, H. Bruining and J. C. Francken, "The image iconoscope—a camera tube for television," *Philips Tech. Rev., 13:* 119–133, May 1951 (abstracted in *Jour. SMPTE, 58:* 501–514, June 1952).
5. W. A. Harris, "Fluctuations in vacuum tube amplifiers," *RCA Rev., 5:* 505–525, Apr. 1941; *ibid., 6:* 114–124, July 1941.
6. O. H. Schade, "Electro-optical characteristics of television systems, Part IV—Correlation and evaluation of electro-optical characteristics of imaging systems," *RCA Rev., 9:* 653–686, Dec. 1948.
7. A. Rose, "Television pickup tubes and the problem of vision," *Advances in Electronics, I:* 133-166, Academic Press, New York, N.Y., 1948.
8. Pierre Mertz, "Perception of television random noise," *Jour. SMPTE, 54:* 8–34, Jan. 1950.
9. Pierre Mertz, "Data on random noise requirements for theater television," *Jour. SMPTE, 57:* 89–107. Aug. 1951.

Photographic Instrumentation of Timing Systems

By A. M. ERICKSON

Time-action marking at film speeds from 2000 to 8000 frames/sec and some of the circuit requirements which must be met to obtain clear edge marks on motion-picture film are discussed.

Photographic timing has become necessary in the field of instrumentation. Primarily time is correlated with an action on motion-picture film. It gives facts about that action which otherwise cannot be obtained. For instance, timing on motion-picture film has been used to study velocity, acceleration, oscillation (pitch and yaw), vibration and position of projectiles in flight. The same photographic system has been used to gather data about explosive trains, shock waves and a variety of other high-speed action phenomena.

Under conditions which dictate the use of high-speed cameras we have found that neon gas ionization is one of the most serviceable methods of film marking. It has been chosen in preference to argon gas ionization, spark gaps and field-of-view devices for general use at the Naval Ordnance Laboratory for the following reasons: (a) neon will mark color film with good contrast (this is not so for argon gas); (b) neon is not affected by atmospheric conditions as in the case of spark gaps, and is relatively simple from a voltage standpoint; (c) field-of-view timers consume valuable picture space and are subject to focus and lighting conditions which are not always the same as that of the subject.

The Naval Ordnance Laboratory has fitted many of its cameras with neon timing lights and has attempted to standardize on the NE-51 bulb, a recent addition to the neon family.

To excite neon gas for clear edge marking it is necessary to produce a pulse of at least 90 v. A duration of not less than 8 μsec and the power to maintain voltage during ionization is also necessary. The "work horse" timing system (shown in Figs. 1 and 2) more than meets these minimum requirements. It consists of three units, an oscillator, a pulse generator and a six-channel cathode follower.

The oscillator is a battery-powered fork with good stability which delivers

Presented on October 9, 1952, at the Society's Convention at Washington, D.C., by A. M. Erickson, Naval Ordnance Laboratory, White Oak, Md.
(This paper was received April 30, 1953.)

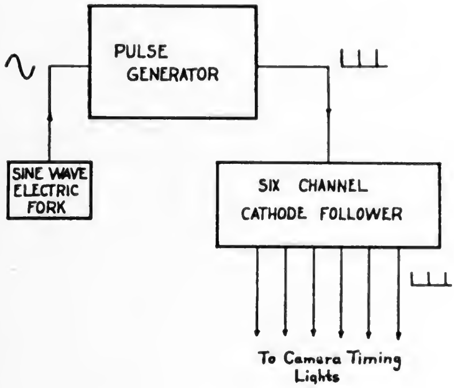
Fig. 1. Pulse timing system and neon timing light mounted on upper sprocket clamp of an Eastman High-Speed Camera.

about 25 v to a high-impedance load. Its output is used only to control the repetition rate of the pulse and is dependable under a variety of field conditions.

The a-c powered pulse generator, which is controlled by a stable-frequency source, is independent of voltage and frequency variations of the power line. For operation of only one camera this generator is connected directly to the camera marking light.

To time up to six cameras a six-channel cathode-follower amplifier system is used. This unit when driven directly by the pulse generator develops marking pulses on six separate circuits. Each light is given its own individual circuit mainly for insurance. It has been found that neon bulbs exhibit high firing potentials after considerable use, some measuring above 100 v, as compared with 75 v for new bulbs. If several used bulbs are placed across the same circuit, and the combined load limits peak-pulse voltage to 90 or 100 v, an old bulb may not fire, or it may fire erratically and give false timing information which is more detrimental than no timing at all. Many field tests are conducted specifically for the photographic results. The total cost of test operations may range from $100 to $40,000 a day with complete destruction of the ordnance material under test. In the face of such expensive operations it is unwise to design borderline features into instruments which add to this expense.

Each cathode-follower output circuit is equipped with a current-meter switch and a variable-series resistance. Exposure current, a predetermined value of approximately 1 ma (average), is adjusted by varying the series resistance. This provides an indication of proper intensity regardless of line length, and proof that the exposure light is functioning. This facility of remote test and exposure adjustment is valuable in



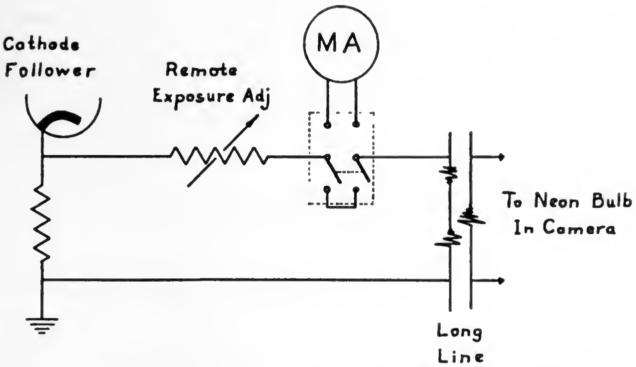


Fig. 2. (Above) Pulse timing system. (Below) Detail of the pulse timer output circuit.

both time and labor to the photographer when his cameras are spread over a long firing range or at the top of range towers.

In addition to time marking, some instrumentation requires "start-action marks" on the film to indicate when an event takes place, such as the breaking of a wire, the closing of a firing key, or the attainment of certain water pressures. When action begins with the firing of a detonator by electrical means, it is better to tap the firing circuit for start information if it is possible. Any electrical connection made to firing circuits other than those necessary to fire the detonator are considered a safety hazard and precautions must be taken to eliminate prematures. The circuit shown in Fig. 3 will not only provide a pulse of the proper impedance and polarity but will fire the detonator and under certain circumstances provide bias to gate a timing circuit closed until start marking has taken place.

When a double-pole relay is used with a firing circuit over one set of contacts, and a pulse circuit over the other, error will always result when trying to close two sets of contacts at the same time. This error is usually of the order of a few milliseconds even though both sets of contacts are on the same relay, and cannot be depended upon for accurate or close timing. The Naval Ordnance Laboratory system

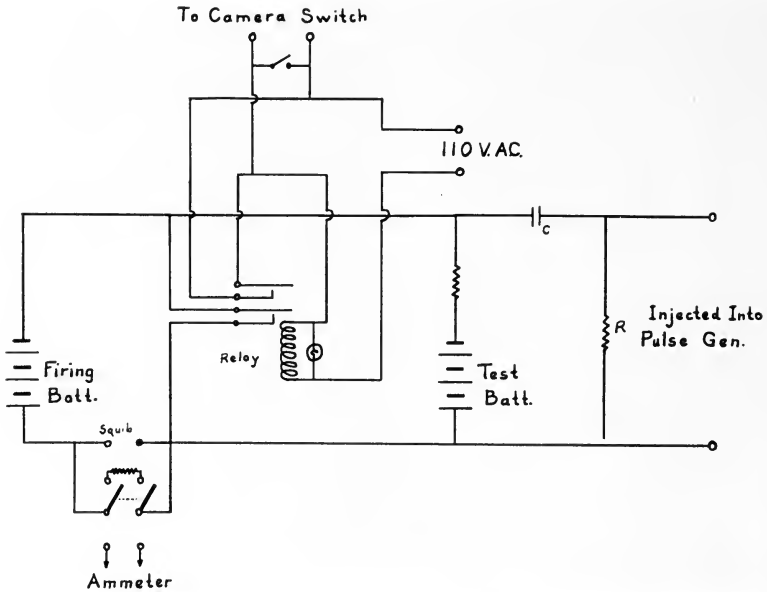


Fig. 3. Diagram of start-marking system for marking motion-picture film at instant firing key is closed.

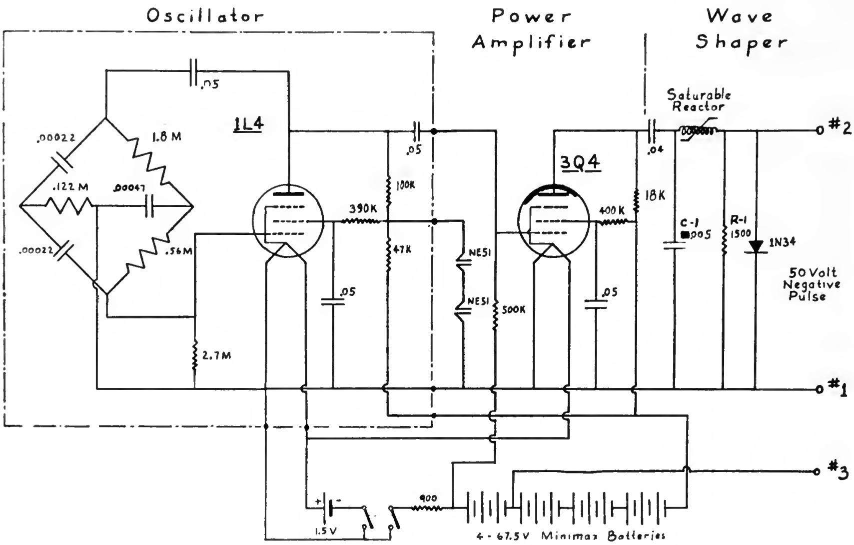


Fig. 4. Portable battery-powered pulse timer designed for field use, incorporating magnetic amplifier principles to shape the timing pulse.

uses one set of contacts to close both circuits. In stand-by condition two batteries are connected in parallel through the detonator and a large resistance. A charging or discharging current will flow between two identical batteries until both batteries are of the same terminal voltage. Even the most sensitive primers will stand 100 μa without damage to the squib wire. A microammeter is available to test any lack of voltage balance prior to connecting the primers in the circuit.

The start-mark circuit is connected to the grid of a voltage-amplifier stage in the pulse generator as shown in Fig. 2. It delivers a pulse with a delay time governed by R and C of Fig. 3. This results in a film which contains a start mark injected into the regular timing pulses. A disadvantage from a data reduction point of view is that interpolation is necessary to determine the time interval between the start mark and the next timing mark.

One of the main sources of trouble in field instrumentation originates from field power supplies. When these supplies are furnishing power to both high-speed cameras and timing equipment, a peak load caused by camera "start up" momentarily disables the timing equipment and results in a loss of timing marks during the action period. A completely battery-powered timer is useful under these conditions. The timer must be stable and should develop enough power to meet the previously mentioned requirements. These features are incorporated into a new design which uses magnetic-amplifier principles for wave shaping (see Fig. 4).

The circuit generates a stable sine wave, power-amplifies this sine wave and converts the wave into a pulse. The oscillator is an RC-controlled feedback circuit with good stability. It has been constructed as a plug-in unit to change frequency by changing the entire oscillator. The second stage operates as a class "A" amplifier and develops power to drive the pulse-shaping circuit. The shaping is done by passing the sine-wave current through a saturable reactor. As the core is driven into saturation the reactor loses its inductance and transfers its inductive voltage drop to the series resistance R-1. The sudden decrease in load resistance causes condenser C-1 to "dump" its excessive charge through R-1 and causes a still further increase in voltage. The net result is sharp pulses of about 50 v developed across a relatively low impedance. These pulses plus a d-c bias make up enough voltage to fire neon timing lights. The pulses appear across terminals #1 and #2. The pulse and the bias may be obtained without additional components by connecting the marking bulb across terminals #2 and #3. This places the first battery of the "B" supply in series aiding with the output pulse.

Timing marks without an associated picture can also be useful under certain conditions. In the development of an arming vane for a missile, instrumentation was needed to determine angular velocity and acceleration of the vane under flight conditions. The problem was solved by the simplest kind of pulsing circuit (see Figs. 5 and 6). The recorder consists of a photographic film rotated by the arming vane. As the film turns, a pulse-driven exposure light marks the perimeter of a disk to give time-motion characteristics at the rate of approximately one mark every 25 msec. With a 100:1 step-down gear ratio, and an assumed vane speed of 6000 rpm, the film disk was estimated to make not more than 1 rps. This spaces the timing marks about 9° apart when the vane is rotating at its maximum estimated speed.

"Start" and "stop" switches are placed on the outside of the missile, while all other components are fitted in the booster cavity. One switch puts the circuit into operation just before launching, and the other disables it

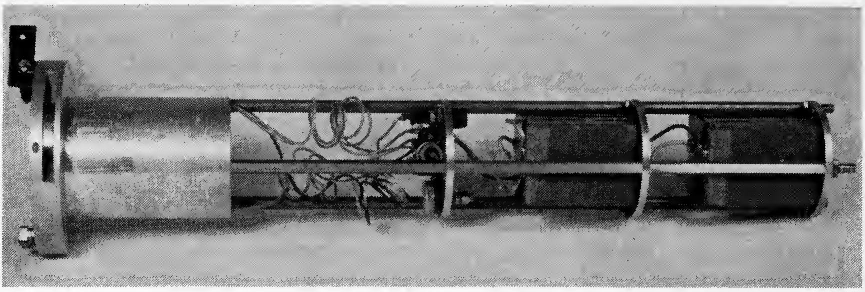


Fig. 5. Rocket arming-vane timer which mounts in a rocket case. The timer marks a rotating disk of film to record the velocity and acceleration of the arming vane during flight. Left to right: film-disk housing; circuit shelf; batteries.

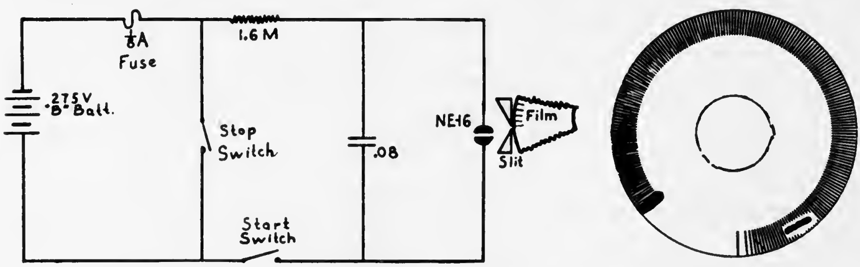


Fig. 6. (Left) Schematic of the basic RC-pulsing circuit installed in the rocket booster cavity. Start and stop switches are mounted on the outside of the rocket case. (Right) Diagram of time-recorder test film; one space equal to 23.8 msec.

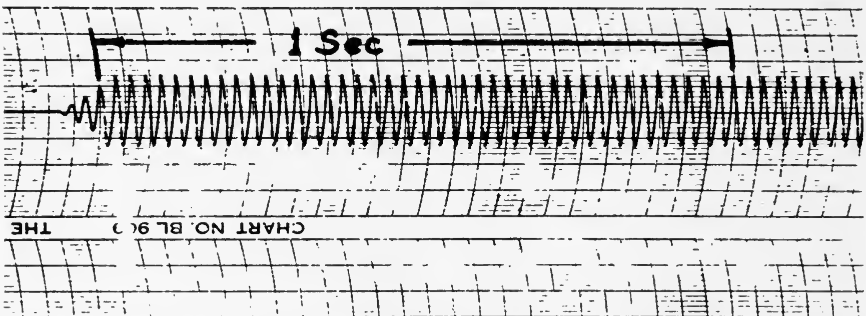


Fig. 7. Photograph of a permanent frequency record made by connecting a Brush Pen Recorder across the battery terminals of Fig. 6. This record is made just prior to rocket launching. Paper speed, 5 in./sec; pulse rate, 42/sec.

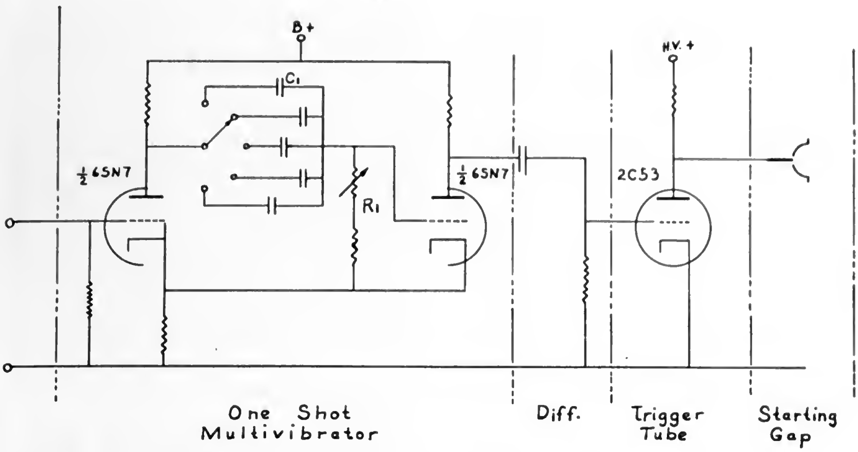


Fig. 8. Diagram of a delay timer designed to trigger photographic spark stations in a ballistics range.

during flight after the record has been taken. Although the system is used at slow film speeds, it can have application in high-speed work if the pulse rate is increased. The waveshape is not a pure pulse, in the sense that it has both a steep rise and fall, but its firing characteristics are such that the lamp receives a maximum current at the instant of ionization and decreases at the RC discharge rate until lamp-extinction voltage is reached. This results in maximum exposure at the leading edge with a fading trail behind it, and furnishes a sharp edge as a reference point on each mark.

The frequency of this generator is dependent upon the characteristics of every component in the circuit and stray capacity of the circuit to ground. Frequency measurements were made by amplifying voltage-notches appearing directly across the battery terminals. Connection to any other point in the circuit gave erroneous readings because of added load or wiring capacity of the measuring equipment. Amplified-voltage notches are recorded as shown in Fig. 7 on a Brush Pen Recorder just prior to launching. This provides a permanent frequency record for data reduction.

The completed unit was tested in the simulation laboratory at an acceleration of 25 gravitational units. This more than exceeded acceleration forces experienced by the unit under launching conditions. No noticeable change in fundamental frequency was measured after the "G" test.

Timing circuits are quite useful in ballistics-range work to trigger microsecond spark lights in photographic stations along a range. An antenna or pickup unit placed slightly ahead of each photographic station senses the passage of a projectile and fires a spark-light source down range to obtain a shadowgraph of the projectile as it passes through the station.

In order to do this an electronic delay timer is necessary to receive the sensing information, hold it for a predetermined period of time, and then emit a signal to fire the spark light. A timer which will perform these tasks is shown in Fig. 8. The first part of the circuit forms an oscillator which reacts only when it receives the "sensing" signal. It is a "one-shot" multivibrator and has most of its application in radar as a gating or pulsing circuit. The delay time is dependent upon values of RC-coupling components which have been made variable in this circuit to cover the range of delays needed to match projectile velocity.

A missile traveling at 3000 fps takes about 660 μsec to move 2 ft between the sensing antenna and the photographic plate. The sensing antenna immediately pulses the delay circuit to start it timing. The one-shot multivibrator, 610 μsec later, sends a pulse to the trigger tube which has a normal delay of approximately 50 μsec. Together the two delays make up a required total of 660 μsec and fires the main spark light just as the projectile is in position for exposure. The trigger tube in a stand-by condition is drawing its maximum current and holds the auxiliary spark-gap voltage to a minimum. Application of the pulse causes the tube to cut off and allows full-supply voltage to reach the auxiliary gap and fire the main discharge gap.

This high-voltage type of circuit can easily be adapted to function as a start-marking system in high-speed motion-picture cameras. It can be used by placing the spark gap in a camera as an auxiliary to the regular timing light, or it can be connected to the camera frame on one side and the spark allowed to jump to one of the leads of a neon-bulb marking light. This method of start marking does not load the regular timing circuit and can delay marking action for convenience in data reduction or for correlation with other camera records taken of the same action. Also it can be used as the regular timing system to furnish both timing marks and start marks. If a fixed bias instead of a pulse is applied to the circuit at the instant of starting, the film will receive a series of marks spaced in time according to the delay time of the circuits. Data reduction still depends upon a measurement ahead of the first timing mark to find the start mark because the delay timer receives the start information but does not give it out for one cycle.

Discussion

Robert D. Shoberg (White Sands Proving Gd.): I assume you had trouble firing the NE-51 lamp in total darkness. How did you overcome that?

Mr. Erickson: There was no trouble at all as long as we exceeded the firing potential. The regular firing potential of a new bulb is around 75 v. In darkness I don't know what it is. We usually apply about 125 v across a circuit impedance of not more than 1000 ohm.

Mr. Shoberg: We tried that, and had a lot of trouble. Finally we discarded the equipment we were using and put in the Fastax timing system, using an NE-51 lamp.

Mr. Erickson: We have had absolutely no trouble in firing as long as we get above 125 v. An old bulb, remember, will have an increase in firing potential.

Mr. Shoberg: We aged the lamps.

Mr. Erickson: How much power did you use? What kind of circuit did you use to drive it?

Mr. Shoberg: Up to 125 v. We have a very elaborate timing system there, but we ran into the same problems you did. We checked before we ran and everything was going fine. We opened the door of the camera and the lamp was not glowing. We closed the door and made the test — and the film came out blank. The lamp would not start in total darkness at the same voltage it would in the dark.

Mr. Erickson: We have had no trouble.

Mr. Shoberg: You solved the problem by increasing the voltage on the lamp?

Mr. Erickson: Yes. That takes care of it every time.

Mr. Shoberg: It was not practical for us to increase the voltage to that extent so we substituted the NE-66 lamp for the NE-51 lamp. This eliminated our trouble as the NE-66 fires at considerable lower voltage than the NE-51.

Gerald Doughty (*Aberdeen Proving Gd.*): We ran into the same thing. We are using about 65 v d-c bias, with a pulse about 22-μsec duration and 120-v amplitude above bias. The bias serves to keep the bulbs ionized without producing enough light to affect the film traveling at low speeds. Failures of time records practically disappeared. Line-voltage drop due to heavy current loads from camera runs affects this system less than any other we have tried. Bulb life is about 10-min operating time, or approximately 200 Fastax runs.

Mr. Erickson: Regardless of the pulse height?

Mr. Doughty: That is right. We have no trouble from film fogging. The bulbs do get old, and sometimes too old before we change them. But generally they work pretty well.

Mr. Erickson: I don't think we have ever had a bulb fail because of its old age.

Major P. Naslin (*French Laboratory of Armaments*): Would it be possible to make your vibrator-timer insensitive to a very intensive discharge, say 200 wsec within one μsec, which involves very high terms in the order of several thousands.

Mr. Erickson: I don't know what you mean by making it insensitive. Do you mean in the proximity?

Major Naslin: From being triggered.

Mr. Erickson: The idea is to have the timer not trigger when this high current is flowing?

Major Naslin: Nearby.

Mr. Erickson: If it reaches the circuit, it is bound to make the multi-vibrator operate. If you make the input impedance of that circuit low enough, regardless of what this other thing is doing, it won't affect the vibrator, because it responds only to the bias or signal on the first stage. If this bias is raised high enough, the circuit will go into oscillation.

Major Naslin: Have you done it?

Mr. Erickson: Yes, I have. When we were designing this equipment for the Naval Ordnance Laboratory pressured range, the circuit that I showed you (Fig. 8) was considered in the final photographic station. This photographic station setup required the projectile to be charged by a 20,000-v source, and there was a lot of high voltage around near the trigger circuit. We had a common feed source for the high voltage which goes down the range to charge each of the spark-light condenser units also located near the trigger circuit. The discharge of the first spark light, which is a sudden drain and a very high current flow, can affect the sensing antenna on the following station and make it start timing before it is supposed to. We overcame that by merely decreasing the impedance of the circuit being affected. Of course, proper shielding and grounding are necessary.

Follow-up of the Discussion

(*Submitted by the author, April 30, 1953*): In answer to questions about firing potentials the author has conducted a series of tests on 10 NE-51 neon bulbs picked at random. They were placed in a lighted room and individually connected to a d-c voltage with a time constant of 10 sec, that is, 10 sec were required to raise the voltage from 0 to 150 v. Firing potentials for the bulbs ranged from 70 to 76.5 (see Table I).

Table I. Firing-Potential Data Taken on 10 New NE-51 Neon Bulbs (Firing-Potential in Volts).

Bulb No.	1	2	3	4	5	6	7	8	9	10
Daylight	75.0	71.5	72.0	81.0	70.5	71.5	76.5	74.0	74.5	73.0
3 min dark	78.5	81.0	74.5	93.5	90.5	83.5	91.0	79.5	84.0	81.0
24 hr dark	80.0	120.0	125.5	107.0	115.0	117.0	124.0	150+	150+	78.5
3 month dark	99.0	95.0	113.0	105.0	98.0	125.0	90.0	72.0	100.0	90.0
2d try	77.0	73.0	78.0	86.0	72.5	81.0	77.0	72.5	75.0	75.0

After 3 min of darkness the same bulbs exhibited ignition potentials between 78.5 and 93.5 v. After 24 hr of darkness two bulbs failed to fire with up to 150 v. on the first try. The remaining eight bulbs fired between 78.5 and 125.5 v. The two that did not fire broke down at 74.0 v and 109.5 v on the second try. After 3 months of darkness the firing potentials ranged from 72 v to 125 v with no failures. Firing all bulbs the second time decreased the range from 72.5 to 86 v.

Some conclusions can be drawn from these tests: (1) NE-51 bulbs are light sensitive; (2) firing potentials are generally higher in the dark than they are in the light; (3) successive application of voltage causes a random decrease in firing potential with a lower limit being the daylight-firing voltage of that specific bulb; and (4) for start-marking action a pulse in excess of 150 v must be applied for reliable results.

Contrary to popular belief, a pulse generator designed to drive neon timing lights must have the characteristics of a power circuit, not just voltage amplification. A timing light represents a changing load according to its conditions. When fired it represents a very low resistance and the driving circuit must be designed to deliver ample current through this low resistance and still maintain pulse voltage in excess of bulb-firing voltage.

Therefore the generator output should be of the cathode-follower type, rather than a plate-loaded circuit. Power tubes such as the 6L6, 6V6, 6Y6 and 6AS7 with proper circuit connections will solve most timing-light problems.

Discussion of NE-51 Lamp

(*Prepared by H. M. Ferree, General Electric Co., Nela Park, Cleveland, May 7, 1953*): It has long been known that glow lamps such as the NE-51 do have a definite "dark effect." When the lamp must be enclosed in a light-tight enclosure such as a camera, the starting voltage of the lamp may be increased as much as 20 to 50 v, d-c.

The test data presented by Mr. Erickson agree reasonably well with our experience, and the solution he offers, namely increasing the applied potential well beyond the normal starting voltage, has in most cases proven to be the simplest and most satisfactory.

Also, the time required for ionization is reduced as the voltage in excess of normal starting is increased. In some applications this may be a determining factor.

As Mr. Erickson points out, the starting voltage of a glow lamp increases with age. Therefore, where there are no other limiting conditions on the applied voltage, voltages in excess of the 150 he mentions might be used to extend the usefulness of the lamp.

The M-45 Tracking Camera Mount

By MYRON A. BONDELID

A new, versatile tracking camera mount is described. This instrument was developed to solve certain problems in ballistic data-gathering activities. Performance and operational characteristics of the mount, camera types and uses, lenses, communication, orientation, timing and power requirements are also discussed. The tracking camera mount is a completely independent unit, supplying its own power, and capable of negotiating heavy sand.

At the U.S. Naval Ordnance Test Station, Inyokern, China Lake, Calif., a new, versatile tracking camera mount has been developed to solve certain problems known as "attitude" in ballistic data-gathering activities and to provide an easy method to track fast-moving objects.

Testing of rockets and guided missiles must be done under dynamic conditions in which the component is allowed to function under normal environmental conditions. The recording of the necessary test data becomes a difficult task under these conditions since no direct mechanical contact with the test object is possible when it is in free flight.

Bell & Howell Eyemos and Superspeed Cameras comprised the bulk of the early photographic recording test equipment, but it was realized early that the exacting demands required of the data recorded left much to be desired. As this was a special need, little equipment could be utilized as manufactured, and physicists, engineers and photographers pooled their knowledge and experience to adapt or devise instruments that could better meet the rigid requirements of determining trajectory, velocity, acceleration, attitude and other data necessary to evaluate scientifically the performance of rockets and missiles under test.

Trajectory, velocity and acceleration are determined by the Askania Cinetheodolites and Bowen Ribbon-Frame Cameras. Attitude is often determined from the Askania, but because of image size, quality and frame rate this is usually insufficient. Therefore attitude, which

Presented by abstract only on October 10, 1952, at the Society's Convention at Washington, D. C., and in full on May 1, 1953, at the Society's Convention at Los Angeles, by Myron A. Bondelid, U. S. Naval Ordnance Test Station, Inyokern, China Lake, Calif.
(This paper was received on April 3, 1953.)

This paper is published for information purposes only. It does not represent the official views or final judgment of the Naval Ordnance Test Station, and the Station assumes no responsibility for action taken on the basis of its contents. The M-45 Tracking Camera Mount has not yet been fully developed and several changes mentioned in this report might occur differently in the final form. It is being developed under Task Assignment No. TP 872-H.

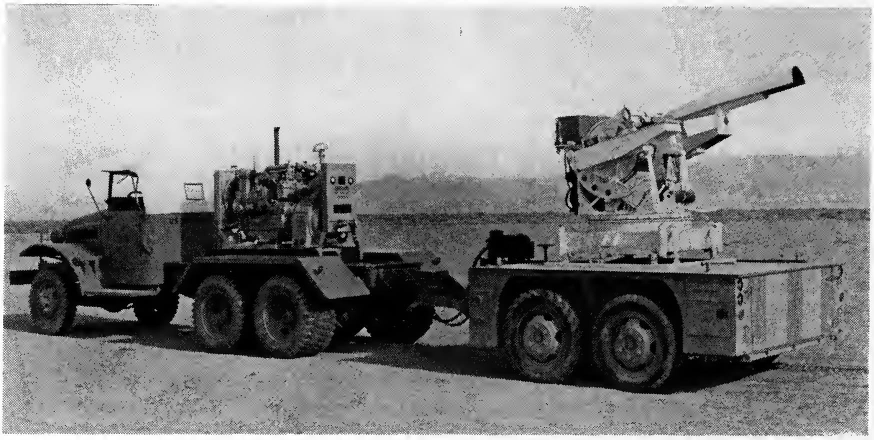


Fig. 1. The M-45 Tracking Camera Mount powered by a 20-kw 3-phase 208-v a-c diesel generator located on the prime mover (*Official Photograph,* U.S. Navy).

includes pitch, yaw and roll, missile-booster separation, off-range deflection, launching, time of flight and detailed motion are usually determined from Mitchell, Fastax, or other high-speed cameras.

A basic approach to the problem of measuring attitude is to take photographs of the missile from at least two positions with motion-picture cameras equipped with long focal-length lenses so that the pictures will be large and easily measured. The apparent angle of the missile with respect to each camera reference system is measured and these data are then mathematically converted to attitude angles with respect to the range coordinate system.

Attitude measurements determine the orientation of the missile at a predetermined sampling rate. The orientation measures are classified according to their relationship to the line-of-flight axis of the missile. Roll or spin describes rotation about this axis, while pitch and yaw describe the vertical and horizontal components of transverse oscillations of the missile about its center of gravity.

In the design and subsequent redesign of a test missile it is necessary to know the aeroballistic characteristics of the missile; attitude in flight is the chief of these characteristics and is an important piece of information on the flight of a missile.

In the past the Mitchell Chronographs were mounted on heavy-duty tripods and hand tracked with the aid of an auxiliary optical system. Lenses of 17- to 20-in. focal lengths were used with these cameras. As emphasis on attitude measurements increased, and the desire for more accurate data developed, longer focal-length lenses became a necessity. However, the longer lenses required more accurate tracking, and soon it was realized that a mechanical means was needed to track fast-moving objects.

As a result of tests conducted at NOTS, an Army model M-45 50-caliber machine-gun mount was acquired and used as the tracking mechanism. After some alterations and additions (such as removing the machine guns and installing cameras and lenses) the M-45 Tracking Camera Mount, popularly known as the "Gooney Bird," emerged.

Early versions of the "Gooney Bird" were mounted on an M-20 trailer. Power was received from batteries on the mount

Fig. 2. Cameraman operating M-45 Tracking Camera Mount (*Official Photograph,* U.S. Navy).

and separate generators powered the cameras.

The latest version of the M-45 is shock- and spring-mounted on an M-1 Tandem Trailer with stabilizing jacks and leveling provisions. A refractor of 48-in. focal length is mounted on one side of the operator and a half-scale version of this same lens is mounted on the other side. Pictures for attitude purposes are recorded by means of a 35mm Mitchell Chronograph Camera. A 16mm Mitchell Pictorial Camera may be used for documentary movies or a Fastax camera for super slow-motion studies. Each "Gooney Bird" is powered by its own generator system, which is mounted on a $2\frac{1}{2}$-ton 6×6 truck used as the prime mover for the M-45, and is thus a complete, independent unit capable of negotiating heavy sand encountered in the Mojave Desert (Fig. 1).

Performance and Operational Characteristics

The elimination of footwork around a tripod and the ease and speed of control of the M-45 have resulted in an appreciable gain in missile-tracking rate. Performance of the M-45 is very satisfactory when it is in good condition. In field use it is difficult to maintain optimum performance over sufficiently long periods. Tracking rates of 60 deg/sec are attainable in order to have a margin of safety beyond the experienced maximum rates of approximately 40 deg/sec. In tracking it is important that the tracking rate be similar to the speed of the missile to prevent blurred images which are difficult to measure. Acceleration characteristics are generally satisfactory, although some decrease in acceleration in elevation has been observed after some use. It is easier to track a fast-moving object in elevation only, without the azimuth component.

Chatter in elevation causing double images and the loss of tracking performance, both due to the old large-diameter ball bearings, have been eliminated by installing new tapered roller trunnion bearings. The present azimuth roller bearing is satisfactory and capable of smooth operation when clean, but it is poorly sealed and maintenance requires the disassembly of the mount.

The turret structure contains all of the rotatable supporting elements of the mount. The trunnions which carry the lens, camera and binoculars are mounted to elevate through an arc of $-10°$ to $+90°$ from the horizontal. The turntable, upon which the trunnions are mounted, rotates through 360°. The operator's seat, which does not move in elevation, is centralized in the mount structure and is tilted backwards about 45° to permit coverage of the full elevation range. The seat is adjustable so that the operator may regulate his position in order to follow the sight with minimum head movement (Fig. 2).

The mount movement and camera operation are controlled from a pair of control handles through a mechanical linkage mounted on a column which is straddled by the operator and within easy reach of his hands. The control handles may be moved in a vertical or horizontal arc or in a combination of both. The degree of movement and position of the handles control the speed and direction of the mount. Off-On switches, one mounted on each side of the control handles, actuate relays in the junction boxes which carry power to the cameras.

Camera Types and Uses

Instrumentation used on the M-45 is shown in Fig. 3. The 35mm high-speed Mitchell Chronograph Camera (Type B), which utilizes the 48-in. lens, is used to obtain the bulk of the required attitude data. This instrument combines the advantages of timing, large image, high speed and high tracking rate on the M-45.

The Mitchell Chronograph was designed with the cooperation of the U.S. Navy to meet special photographic requirements of the service. It is an intermittent-type, 35mm motion-picture camera. In order to insure the accuracy and precision required, the mechanism is manufactured to extremely close tolerances. The term "high-speed" is derived from the fact that the camera will operate at any speed up to 128 frames/sec using a 110-v a-c/d-c electric motor. A 12-v d-c motor is available for lower speeds.

A chronograph head with a 1/100-sec stop watch attaches directly to the specially designed camera base and photographs the image of the chronometer onto a corner of the frame on the emulsion side of the film utilizing the camera shutter.

The 16mm Mitchell Pictorial Camera, which utilizes the 24-in. lens, is used for documentary purposes only. This camera is similar to the 35mm Mitchell Chronograph except that it is not equipped with provisions for timing, and uses 16mm film.

The 16mm Eastman High-Speed and 8mm or 16mm Wollensak Fastax cameras (24-in. lens) are used to study detailed motion, separation of booster from the missile, time to action, and launching of

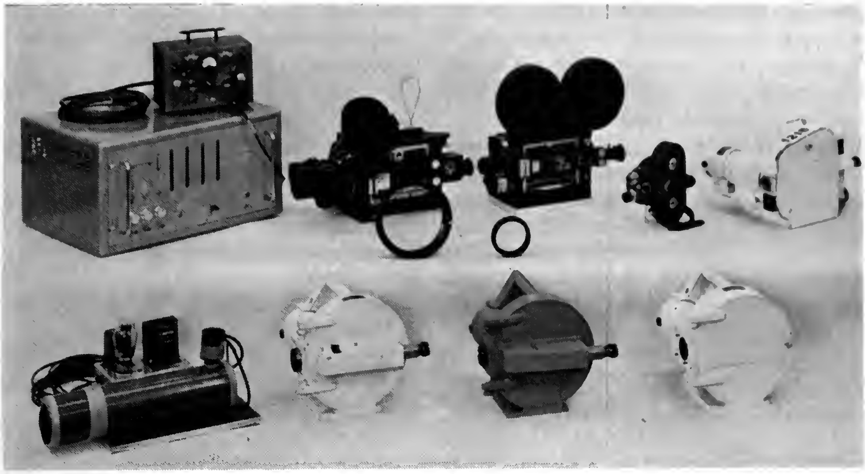


Fig. 3. Instrumentation used on M-45. Left to right, top row: Berkeley Time Interval Meter, 35mm Mitchell Chronograph with 48-in. lens in front, 16mm Mitchell Pictorial with 24-in. lens in front, 16mm Bell & Howell, 16mm Eastman High-Speed; bottom row: photoelectric Cell, 16mm Fastax, 8mm Fastax, 35mm Fastax (*Official Photograph,* U.S. Navy).

missile. These cameras are designed for high-speed photographic work with exposures ranging from 500 frames/sec to 3000 frames/sec in the EHS and up to 14,000 frames/sec in the 8mm Fastax.

Both of these cameras are of the continuous-film-drive type. A rotating optical flat is used to displace the image by an amount equal to the film movement during exposure. This system allows sufficient exposure, with reasonable definition, despite the fact that in some cases the film may be running through the camera at 200 fps. The effective operating time of these cameras ranges from approximately 0.75 sec to about 9 sec, depending on the frame speed.

Timing is provided by means of timing lamps built into these cameras receiving their pulses from a broadcast 1000-cycle pulse.

The 16mm Bell and Howell 70 TA Camera (Northrup modification) is used in place of the EHS and Fastax to study detailed motion, separation of booster from missile, and launching of missile. Normal operating speed is 200 frames/-sec which is sufficient for most high-speed work and eliminates problems connected with prism-type cameras. This camera gives higher resolution due to an intermittent-type motion, and a longer recording time due to a slower frame speed.

A photoelectric cell has been used in conjunction with the 24-in. lens to time an event from launching to burst.

Ansco color film is widely used on all attitude cameras to aid in distinguishing the image on film. The high-speed cameras have given acceptable results up to 500 frames/sec. Missiles have been painted with highly reflective and fluorescent colors to increase their contrast against the blue sky. The most successful colors have been Fire Orange, which also aids immeasurably in visual tracking, and Saturn Yellow.

Lenses

The increased emphasis on attitude measurements pointed up the need for better lenses for the M-45 Tracking

Camera Mounts. At first a 40-in. Bausch & Lomb Telestigmat $f/8$ lens was tried. Because it was meant to cover a large film rather than the 35mm frame size the resolution was poor and hence not suitable for our use. Very long focal-length lenses have been used with some measure of success, but much of the more recent developmental work on attitude cameras has concentrated on lenses of more conservative focal lengths with exceptional image quality.

Two such lenses are now in use on all M-45 Tracking Cameras: the 48-inch $f/8$ Thompson refractor lens, especially designed to cover the 35mm frame, and a half-scale version of this same lens, designed to cover the 16mm frame. The lenses were designed by Kenneth B. Thompson of the Thompson Optical Laboratory, Pasadena, Calif., and manufactured by Aaron J. Otto of Pasadena.

Thompson utilized air-spacing in the elements of the doublet as another degree of freedom for greater correction. This also does away with objectionable cemented surfaces which must be reconditioned often. The lens is sealed to guard against the entry of dust and is mounted in a cell which can be easily secured to the lens tube by four screws.

The front element glass is made of Borosilicate Crown-2 with an index of refraction $n_D = 1.51700$, the rear surface glass of Dense Flint-4, $n_D = 1.64900$. The effective focal length is 48 in. ± 0.25 in., the back focus is 0.989 times the focal length, and the diameter is 6.000 in., making the stop constant at $f/8$.

The elements are made from striae-free glass and the polished surfaces are coated for anti-reflection. Under the Foucault (autocollimated) knife-edge test, the lens shows uniform shadow with no evidence of axial astigmatism. The lens is corrected for longitudinal chromatic aberration for infinity focus. There is no turned-down edge figure and the test glass patterns were symmetrical to one-quarter fringe. Kenneth B. Thompson wrote that the design had exceeded his fondest expectations and compared the lens with the Rayleigh-Conrady tolerances as follows:

Aberrations	*Rayleigh-Conrady Tolerances*	*Residual Aberrations*
Marginal Spherical ($4\lambda/\sin^2\alpha'$)	0.02367 in.	0.00164 in.
Zonal Spherical ($6\lambda/\sin^2\alpha'$)	0.033 in.	0.0011 in.
Saggital Coma ($\lambda/2 \sin \alpha'$)	0.00018 in.	0.00009 in.

(λ is 0.000022 in. and $\sin \alpha'$ is $\frac{1}{2} \cdot f/\text{no.}$)

Performance tests made on the 24-in. lens show by visual observation that it is capable of resolving about 200 lines/mm on the optical axis and 100 lines/mm at the extreme edge of the field of a 16mm frame. The superb performance of the 48-in. lens has been aptly demonstrated by the resolving on film of tree branches at a distance of 15 miles.

The lens, as has been stated above, is mounted in a cell which can be easily secured to the lens tube by four screws. The lens tube has a metal shield protecting it from the sun, and after the lens is in place a lens shield 1½ ft long further protects the lens. The camera, rather than the lens, is focused by means of a smooth-riding platform suspended by ball bushings and actuated by a rack and pinion. This method of focusing, developed at NOTS, permits optimum focus of the lens with comparative ease.

Orientation

The accuracy of pitch, yaw and roll measurements depends to a large extent on the levelness of the M-45. At low elevation angles the effect of a level error may introduce an error in yaw measurements of twenty times the level error itself. By orienting the M-45 immediately before or after an event it is possible in assessing the data to adjust the error.

At several permanent stations where

the M-45's generally are located are three red-and-white striped telephone poles placed 90° apart at a radius of about 1 mile. At the top and bottom of each pole targets are located very accurately to indicate perpendicularity. The operator takes short bursts of film on each pole.

To determine the out-of-levelness of the M-45 the film is assessed by placing cross-hairs on the targets and along the edge of the film and the angle determined. The correction to be applied to the assessed data can be computed from these measurements.

Timing

Timing for the 35mm Mitchell Chronograph is accomplished by photographing the projected image of a 1/100-sec 3-sec sweep stop watch or a 1/100-sec single-sec sweep electric clock onto a corner of the frame on the emulsion side of the film utilizing the camera shutter. Zero time of missile firing is indicated by a flashbulb at the launcher. The 16mm Mitchell Pictorial has no provision for timing. In the future the 35mm Mitchell will record time by means of a binary counter in place of the stop watch or electric clock.

The Fastax and Eastman high-speed cameras record timing by means of broadcasted pulses. The APR-13 transmitter, a modified version of a "tail warning type of radar," is used for putting the timing marks on the edge of the rapidly moving film. The frequency of the transmitter is 400 mc. As now used it is a pulse-modulated transmitter using 1000-cycle and 200-cycle synchronized pulses. At the receiver, which is a modified APS-13 receiver, the pulses light neon bulbs. The antenna for the receiver is a folded dipole.

Zero time of missile firing is indicated on the edge of the film by the start of the 1000-cycle pulses, the 200-cycle pulses being on continuously. Also, the 200-cycle pulse is of longer duration, thus making a larger mark on the film edge.

The range of the transmitter is approximately 5 miles and at the present time is being increased to about 10 miles with a new NOTS design of transmitter.

In the case where the M-45 is too far from the broadcasted pulses, a 1000-cycle "pulse generator" (NOTS designed and constructed) is used. Zero time from the pulse generator is indicated by the start of the 4-cycle pulse used by Askanias and other instrumentation. The 1000-cycle pulses from this generator are not synchronous with the broadcasted 1000-cycle pulses at Fire Control.

In the Fastax and EHS cameras an NE51 neon bulb is used. The pulse amplitude to the neon is approximately 180 v. No resistor is used in the circuit due to the high brillance of the neon necessary to show on the high-speed film. A special holder designed at NOTS is used to place the neon bulb in close proximity to the film.

At the present time no provision has been made for timing on the Bell & Howell 70 TA Camera.

In the case where a missile detonates in the air or around a target, a photoelectric cell will record the change in light intensity on an oscillographic record which was started when the missile was launched and recorded the 1000-cycle pulses, thus timing an event quite accurately.

Communications

The communication equipment for the M-45's consists of two identical sets of the Navy Type TCS-12 transmitter and receiver. One set is located on the M-45 itself and operates from the batteries through a 12-v d-c dynamotor power supply. This enables the operator to listen to a count-down over earphones or small speaker located close to his ear and to report coverage while seated in the mount. The other set, located within the trailer, is equipped with a large speaker and operates from a TCS-AC 110-v power supply. It is a stand-by radio to conserve batteries and is used to carry necessary traffic such as warnings and progress of preparation previous to an actual event.

This equipment is primarily used on MHF in general ground range communications between the master control station, mobile units, and M-45 operators.

A VHF BC 639 receiver with an a-c power supply is also used for the monitoring of aircraft frequencies when aircraft tests are being conducted.

Power Requirements

The $2\frac{1}{2}$-ton General Purpose 6×6 International Truck is used as the prime mover for the M-45 Tracking Camera Mount. A 20-kw, 3-phase, 208-v, a-c diesel generator is mounted on the rear of the truck and supplies the power for the mount, cameras and communications. Each "Gooney Bird" is thus a complete, independent unit capable of negotiating heavy sand and able to move into any position desired.

The power drive on the mount consists of a Maxson variable-speed drive with a 12-v d-c electric motor. On several mounts, two 6-v batteries furnish the power to drive the turret structure and to power the communications on the mount. On one mount a 12-v d-c rectifier system has been added in place of the batteries and operates from the generator. Already placed into production are plans for operating the mount by a 3-phase, 208-v a-c motor and providing all M-45's with a slip-ring assembly to operate all equipment on the turret structure.

The power requirements for the M-45 hence include 3-phase, 208-v a-c for the mount to permit tracking in azimuth and elevation, 110-v a-c for the Mitchells, EHS, communications and timing, and 250-v d-c for the Fastax.

Conclusion

Attitude has taken an important role in the evaluation of the flight of a missile ever since the first caveman fashioned his spear and hurled it at his enemy. Scientists need an accurate method to determine the aeroballistic characteristics of a missile to develop it to the highest possible standards of perfection. The M-45 Tracking Camera Mount, though only an interim measure, has proven its worth in obtaining data that would have been impossible using hand tracking methods and inadequate lenses.

Though improvements are continually being made on the "Gooney Bird," it is not to be construed that it is the best or final solution to the problems encountered in the science of rocket photography.

Fundamental Problems of Subscription Television: the Logical Organization of the Telemeter System

By LOUIS N. RIDENOUR and GEORGE W. BROWN

The general problem of encoding a picture for transmission and decoding it at the receiver is considered, with special reference to the privacy problem of subscription, or pay-as-you-see television. Alternative ways of indicating the price of the program and acknowledging its payment are described. The factors which have led to the choice of system elements made in the Telemeter system become clear on the basis of this general discussion.

Subscription television is the name that has been given to a system for broadcasting television programs in such a way that a person desiring to view the program being transmitted must pay for the privilege, precisely as he would pay admission to a theater, stadium or other place of entertainment where such a program might be offered. This is not the place to debate the wisdom or desirability of subscription television, although it may be worth noting that the entertainment world is faced with a difficult financial problem posed by the broad public acceptance of television entertainment. Advertising sponsors of television programs cannot pay the producer of entertainment a sum consistent with what he has been accustomed to obtain by offering his entertainment in return for the payment of an admission fee by each individual patron. Total costs of television programs amount to sums less than five cents per viewer of the program; yet the total budgets represented by this modest cost per head are growing so large that most advertising sponsors are meeting them only with some difficulty.

A scheme which enables each viewer of a television program to pay a relatively modest "admission" fee would make possible much higher budgets for such special programs, with a consequent improvement in the quality of program material. It is largely for this reason that the proponents of subscription television systems are striving to develop effective schemes for making "pay-as-you-see" television practicable.

The Problem of Secrecy

Perhaps the most fundamental problem in subscription television is that of providing suitable means for rendering a *broadcast* television program *private*. The very contradiction in terms of the last

Presented on April 28, 1953, at the Society's Convention at Los Angeles, by Louis N. Ridenour (who read the paper) and George W. Brown, International Telemeter Corp., 2000 Stoner Ave., Los Angeles 25, Calif. (This paper was received April 30, 1953.)

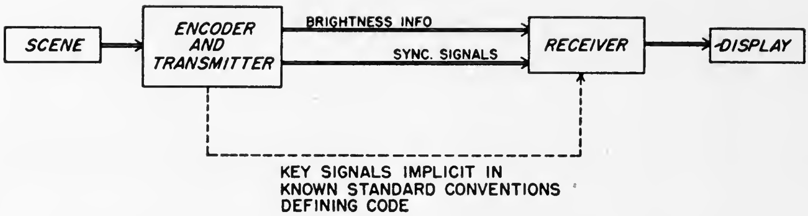


Fig. 1. Conventional television.

phrase illustrates the difficulty of doing this.

To begin with, we notice that the transmission of any intelligence, including the visual and aural signals involved in television, requires a coding of that intelligence into a form that is suitable for transmission (Fig. 1). The receiving apparatus then decodes the received signal and reconstructs from it the intelligence which was encoded at the transmitter. In the case of television, the coding scheme which has been adopted in this country is only one of a large number of possible coding schemes, any one of which might reasonably have been standardized. Indeed, in Europe and parts of South America different coding schemes have in fact been chosen. The successful reproduction of broadcast television programs depends upon the standardization, in transmitters and in receivers, of agreed coding conventions that will be adhered to.

Some of the conventions which are in current use are as follows:

(1) Elements of the scene to be transmitted are scanned in two interlaced fields per frame of 525 lines; 30 frames are scanned per second.

(2) The brightness of a picture element is represented in analog fashion by the amplitude of a quasi-single-sideband carrier on a scale from 0 to 75% of full carrier power; white is represented by zero, black by 75%.

(3) Synchronizing pulses of standard form, duration and location with respect to the video information are transmitted in the range from 75 to 100% of visual carrier power.

These conventions and others which govern the transmission of aural information are, of course, well known. They are mentioned here only to point out some ways in which nonstandard coding of television transmissions can be used to render a transmission "private" in the sense that acceptable reproduction of the visual and aural intelligence being transmitted cannot be accomplished by a standard receiver whose design is based upon the standard conventions.

A point of some importance arises here. Once the conventions for standard coding of television transmissions have been settled, it is then the goal of the receiver designer to build a receiver which will give adequate reproduction of picture and sound when these conventions are used and, in effect, will have nothing to spare. Competition in terms of price is so important that the well-designed receiver will have very little capability outside of the conventions of transmission and reception for which it has been designed. This means that, when we depart from those conventions in order to transmit a subscription television program, the nature of our departure from the accepted standards of transmission and reception will determine the amount and complexity of the auxiliary equipment required at the receiver to enable it to reproduce good pictures and sound under the novel conditions. Quality of program reproduction is, if anything, more important in subscription television than it is in ordinary television. The subscriber, having paid for the program, will expect to receive picture and sound of good technical quality.

The agreed coding conventions for television immediately suggest a variety of ways in which the coding scheme can be changed. The standard line scan can be replaced by a different scanning raster; this may consist of an altered number of lines per field, of fields per frame, or both. It may involve bizarre sorts of scan such as spirals, to-and-fro zigzags, or other patterns; or perhaps an alteration in the order in which lines are scanned in a given field. The representation of brightness can be modified in various ways. The simplest is perhaps an inversion of the analog brightness scale, so that the picture transmitted is related to a standard transmission as a photographic negative is related to a positive. Alternatively, various digital schemes for indicating the brightness of a picture element can be imagined. The conventions regarding synchronizing signals admit of a rich variety of possible variations. The synchronizing signals can be suppressed or changed in form, or a change in the time relationship between the synchronizing signals and the scanning actions which they are to produce can be introduced. There are many other possible schemes for altering the convention under which television signals are encoded, and there is no point in discussing them exhaustively here.

Note that while we have talked only in terms of encoding and decoding the visual information, similar considerations apply to the encoding and decoding of the aural transmissions which accompany the picture signals.

Rather than discussing the relative merits of various specific nonstandard forms of coding, it will be useful to complete this discussion of the secrecy problem by dealing briefly with the manner in which the security of any private television transmission can be maintained inviolate. It is clear at the outset that no single choice of a nonstandard code, however elaborate may be the differences between it and the standard transmission convention, will insure the privacy that is desired. The persistent use of a single code will provide time for analysis of the coding method and the consequent construction and use of unauthorized decoders.

Neither can it be assumed that permanent privacy for coded transmissions can inhere in the constructional details of the decoder mechanism itself. It must

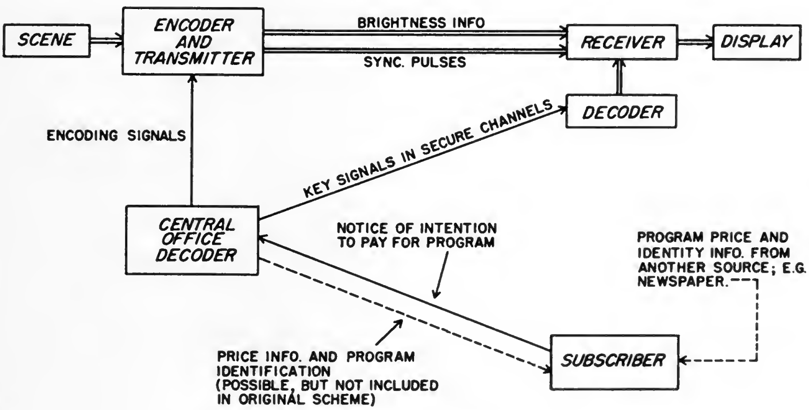


Fig. 2. The original Phonevision proposal.

be supposed that any decoding attachment which can be manufactured cheaply and in large numbers can also be readily duplicated by unauthorized people.

There remain two ways in which the privacy of the coded transmissions can be maintained. The first is represented, for example, by the so-called Phonevision system of subscription television (Fig. 2). A private channel for electrical communications between each subscriber and a central office is postulated in this scheme; because the cost of installing a special channel especially for subscription television would be entirely prohibitive, the use of telephone lines was originally proposed. The private communication channel is used for the transmission of signals which control the action of the decoder, upon indication by the subscriber concerned that he wishes to purchase the subscription program being broadcast. Without these signals, even a decoder of the sort used in the Phonevision system will not successfully decode the coded transmission. It is characteristic of this scheme, which we might refer to as a "closed system," that the necessary secrecy for the decoding process is provided by the existence of a private communications channel between the subscriber and the encoding center which controls the nature of the transmission.

Such a closed system is straightforward and has much to recommend it. In particular, the decoding attachment which must be added to the subscriber's receiver is likely to be simpler in the case of the closed system than it is in the case of the open type of system which we shall discuss in a moment. Unfortunately, the closed system suffers from the profound difficulty that the private channels of communication which it requires represent a vast capital investment on the part of some utility system. Any realistic assessment of the charges which should be made for the use of such channels to provide subscription television yields the result that such a closed system is very expensive to operate. There are other practical difficulties, such as the demand this system would make on the central-office switching facilities of the telephone system, but this is not the place to consider them.

Another form of closed system has been proposed under the name "Subscriber-Vision" (Fig. 3). In this system the subscriber himself cooperates in providing the secure channel for decoding information. This is accomplished through the physical transport of a code card or other

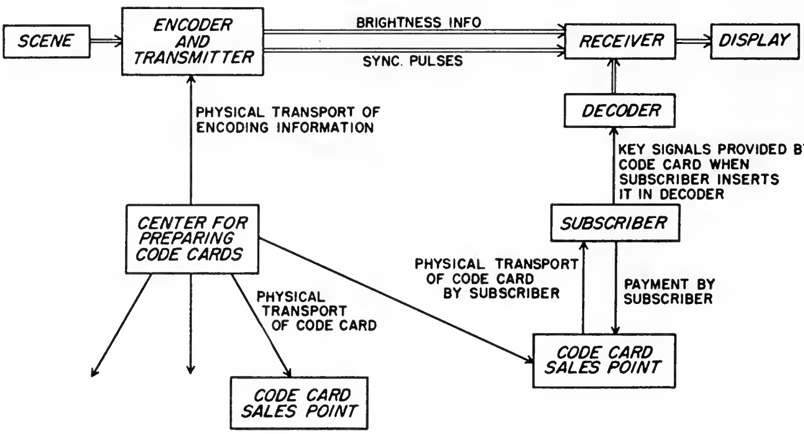


Fig. 3. The original Skiatron proposal.

physical code device; such code cards would be prepared with the necessary information to decode certain future transmissions, and then distributed to various points of sale in the communities where subscription television programs on this scheme were to be offered. A subscriber wishing to purchase a series of programs would purchase the corresponding code card at a point of sale, take it physically to his television receiver, and insert it into the decoding unit attached to his receiver. The decoding unit will be actuated in the proper fashion only when it has been provided with the code card appropriate to the program being broadcast.

Provided that the distribution of code cards can be adequately controlled and counterfeiting eliminated, it is apparent that this also constitutes a closed system, in the sense that a secure communication channel between the encoding center and each subscriber's decoder is provided, this time by the physical transport of a code card from the encoding center to the point of sale and from the point of sale to the subscriber's decoding unit.

In contrast with the closed systems just described is the class of system which does not require a secure channel for the transmission to each subscriber's decoding unit of the decoding information appropriate to the coded transmission being broadcast. In an "open system," as we shall call the latter type, the information necessary to decode the transmission is broadcast with the program. The fact that the transformation necessary to interpret this broadcast decoding information may be altered occasionally does not affect the fundamental difference between a closed and an open system: in the closed system, part of the decoding information is transmitted in a private channel; while in the open system, the decoding information is broadcast with the program.

The secrecy obtained in an open system clearly resides in the provision of a variety of possible codes which is sufficiently rich so that random experimentation with a decoding mechanism identical with that provided to authorized subscribers will still be unlikely to produce an adjustment which corresponds to satisfactory decoding. That is, the open system must rely upon cryptographic security; the closed system, having a private channel, can transmit its decoding messages "in the clear."

As is usual in cryptography, the method of encoding and decoding must not be allowed to remain unchanged for any considerable length of time, since this would provide opportunity for analysis of the code used. A complex sequence of encoding and decoding methods should be used; one of the functions of the decoder can be to provide for the programming of the appropriate sequence. At longer periods, the nature of the programming can be changed by altering settings in the decoder. To continue the analogy with cryptographic communication, we see that this corresponds to a change in the "key" information used to encode and decode messages, and requires a secure means of distributing the key information.

Given adequate cryptographic security, there is little doubt that an open system is preferable to a closed one. It does not involve the vast code-card preparation and distribution problem characteristic of the Subscriber-Vision system, nor does it require of the subscriber that he make an expedition to the store in order to be able to see a show. It avoids adding to the already serious problems of subscription television the further problems inherent in the use of a complicated and expensive wire communications system, as entailed in the original Phonevision proposal.

Accepting this conclusion, let us now discuss some of the ways in which an open system can be realized. We must first settle on the operating characteristics of a satisfactory subscription television system.

Operating Requirements for Subscription Television

The choice of the most desirable operating characteristics for a system of subscription television can be debated, and has been. No attempt will be made here to justify the choices which are characteristic of the Telemeter system, beyond remarking that they are based primarily on two main considerations: (a) convenience to the user of the system, and (b) maintaining as close as possible an analogy with practices which are standard and successful in existing forms of entertainment merchandising. Surely there can be no quarrel with the first consideration; the second has been adopted because of our belief that practices empirically arrived at through centuries of experimentation are likely to be sound. On these bases, then, we believe that the ideal subscription television system will have the following properties:

(1) *It must operate for cash.* With minor and trivial exception, entertainment has never been successfully sold on credit. There is no reason to suppose that the introduction of television as a medium for merchandising entertainment will change things radically enough to overturn the empirically justified view that it cannot be. It is our belief that the only practical way in which cash operation of a subscription television system can be achieved is through the medium of a coin-actuated mechanism.

(2) *Prices for individual programs must be capable of being varied.* Since the production costs of different programs are different, and the value to the viewer even of the same program may be different at different times (e.g., first-run, second-run and third-run motion pictures), a subscription system which operates on a fixed-price basis has surrendered much of its potential flexibility and usefulness.

(3) *Shows must be sold on a program basis, not on a time basis.* A baseball game that goes twelve innings must still be shown in its entirety to a viewer who has paid admission; a person who pays for a motion picture being shown twice in an evening must be permitted to sit through two complete showings of the picture for one admission, if he so desires, just as he could in a theater.

(4) *The identity, price and current status of a subscription television program should be announced for the benefit of those tuning to the channel carrying it, at all times during the program.* In the present Telemeter system, this is accomplished by means of an additional aural channel called the "barker," which is received when a subscriber tunes to a channel carrying a pay show. If the subscriber elects to purchase the show, the barker is replaced by the program sound as soon as the price of the show has been met. In the absence of some such provision, dependence must be placed on other means of informing subscribers as to the shows being offered. While much can be done through newspaper advertising, special weekly or monthly program circulars, spot announcements on radio and television, etc., we are of the opinion that the barker is a very important feature of a proper subscription television system.

(5) *An accurate record must be kept of every show purchased by every subscriber.* While the primary requirement for making such a record lies in the fact that the producer of entertainment is accustomed to being paid on the basis of a percentage of the gross admissions, there are ancillary reasons which make it desirable to keep a complete and detailed record, as we shall see.

We now consider the alternative logical organization of systems that meet these requirements.

Logical Organization of Subscription Systems

The elements of the most general subscription television system meeting the requirements specified in the last section are shown in Fig. 4, together with the information-flow among the various units. The transmitter must be con-

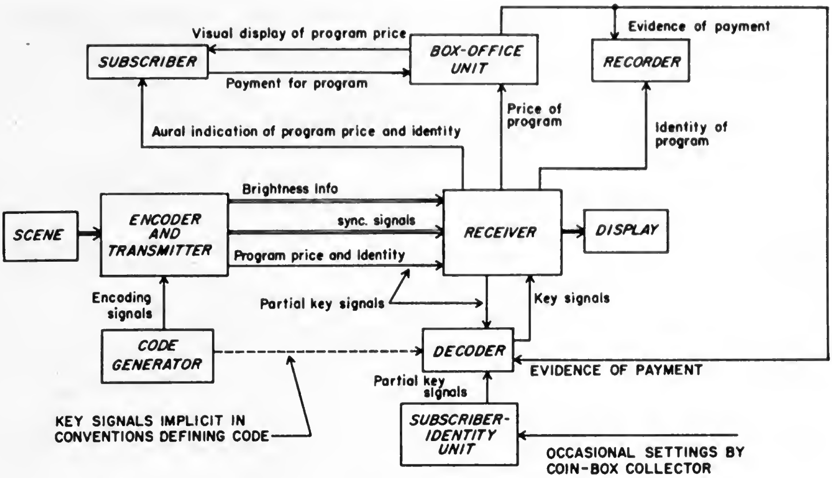


Fig. 4. Elements of the general coin-operated system.

trolled by a code generator which both governs the convention used in encoding and also supplies for transmission key signals that relate to the encoding method in use. The price and identity of the program must also be transmitted, usually in two ways. The "barker" gives to the subscriber an aural indication of price and program identity; at the same time, a suitably coded version of the program price must be transmitted to what we have called the "boxoffice unit." It is the function of this unit to display the program price, to receive the coins deposited in it by a subscriber who wishes to purchase the program, and, upon receipt of the full program price, to present evidence of payment to the decoder, which thereupon commences to decode the program, and to the recorder, which thereupon makes a record of the identity of the program purchased. Coded program-identity signals must also be transmitted, in order to enable the recorder to work.

It will be apparent that the decoder receives information from several sources. We have already noted that it is put into action by an evidence-of-payment signal from the boxoffice unit; this signal may or may not play a part in the actual decoding process, as we shall see presently. In addition, the decoder receives the key signals which the transmitter is sending to accompany the program, it has implicit in its construction some set of conventions defining a class of possible encoding methods, and it may receive from what is called the "subscriber-identity unit" further key signals that play a role in the decoding process. The function of the subscriber-identity unit will become evident as the discussion proceeds.

The fundamental organization of any subscription television system meeting the requirements we have laid down is that shown in Fig. 4. Detailed variation in the system design arises depending on the manner in which the four units of the subscriber's attachment — boxoffice unit, recorder, decoder and subscriber-identity unit — are associated with one another.

For example, consider Fig. 5. Here, by calling upon the subscriber himself to assist in the transport of decoding information, we have reduced to a minimum the amount of apparatus which must be

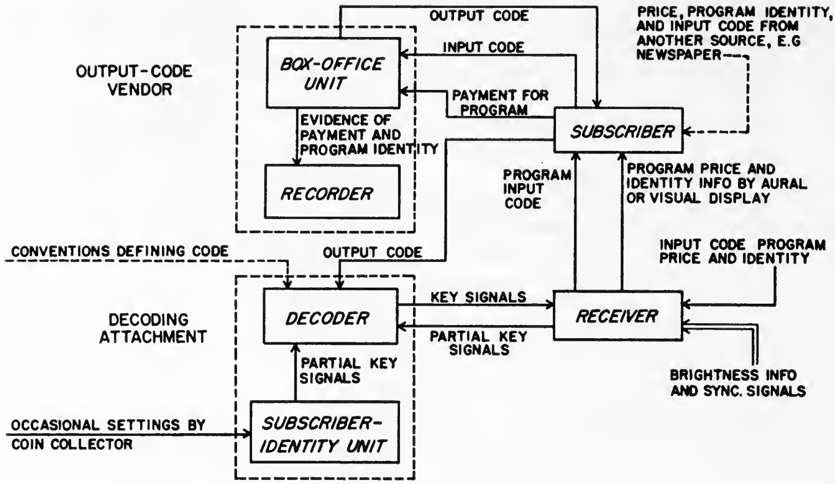


Fig. 5. Coin-operated system with subscriber intervention; remote vendor.

electrically connected to the subscriber's receiver. The boxoffice unit and the recorder have been associated in a device called a "vendor," which can be physically isolated from the "decoding attachment"; indeed, a single vendor can, if desired, serve a number of subscribers. Only the decoder itself and the subscriber-identity unit are associated in the individual decoding attachment.

The system shown in Fig. 5 operates as follows: The subscriber is informed (e.g., by the barker) of the nature and price of the program available on the channel to which he is tuned, and he is given in addition a code message which characterizes the program. This code message must contain an indication of the price and identity of the program, in order for the vendor to work satisfactorily. The subscriber then goes to the vendor and enters the code group characterizing the program, and another code group which serves to identify the subscriber himself. On the basis of these items of information, which together comprise the "input code" of Fig. 5, the vendor prepares itself to receive payment for the program. Upon the subscriber's meeting the price asked for the program, the vendor makes a recording of the identity of the program purchased and the subscriber's identity; it then presents to the subscriber a new code group (the "output code") which may simply be a message or alternatively may take some physical form, such as that of a code card.

The subscriber now returns to his set and enters the output code into its decoding attachment. On the basis of this information and that supplied it by the subscriber-identity unit, the decoder is actuated and the program is decoded. We now see one reason for the subscriber-identity unit. Without it, the full code required by the decoder would be available to the subscriber, and this code would be the same for all subscribers. Collusion among subscribers would then enable a single output code purchased by one subscriber to be used by the entire group, without any record being made of this fact, since the recorder is located in the vendor. It is therefore necessary to render each output code unique to each subscriber, which can be done by causing the input code, and therefore the output

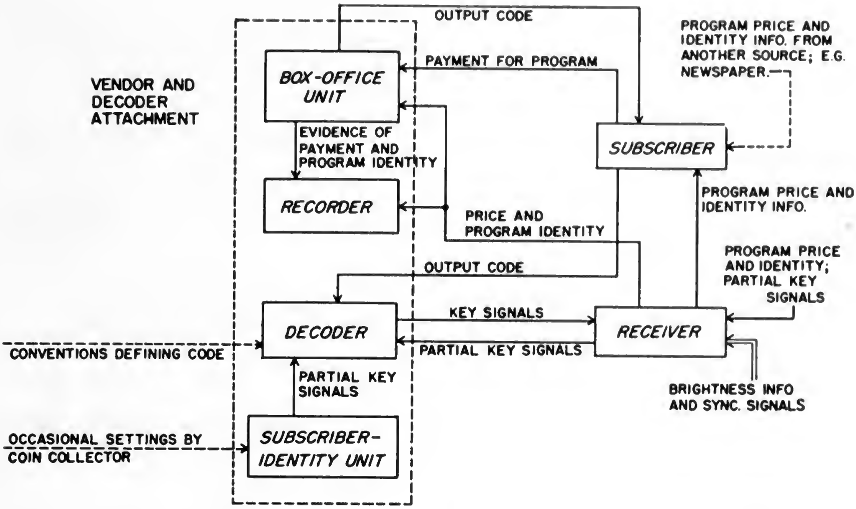


Fig. 6. Coin-operated system with subscriber intervention; automatic input code.

code, to be unique to each subscriber. The various individual output codes are then all translated back into the proper decoding pattern through the intervention of the subscriber-identity unit, whose settings have been chosen to match the variations in output code produced by the subscriber-identity part of the input code.

The system of Fig. 5 represents the maximum degree of subscriber intervention in the decoding process which we think is at all feasible. Figure 6 shows a system which is more nearly automatic.

In Fig. 6, the boxoffice unit and the recorder, which together comprise the remote vendor of Fig. 5, are associated with the decoder and the subscriber-identity unit in the subscriber's attachment, which must be physically and electrically joined to the television receiver. The information on program price and identity reaches the attachment directly from the television receiver, without the intervention of the subscriber. The output code is presented to the subscriber, who enters it into the decoder. As in the system of Fig. 5, and for the same reasons, a subscriber-identity unit is necessary to handle output codes which are unique to each subscriber. The part of the input code which represents the subscriber's identity can be set into the recorder and boxoffice unit in a semipermanent fashion, since the entire attachment is and remains in the possession of a single subscriber.

Another possible system is shown in Fig. 7. Here the subscriber intervenes to enter the input code, which has reached him via the receiver, perhaps through the agency of the barker. As in Fig. 6, the subscriber-identity part of the input code is built into the attachment and need not be entered each time the equipment is used. The output code now goes directly from the boxoffice unit to the decoder, entirely within the attachment. Under this arrangement, there is no longer any necessity for a complicated output code, nor for one unique to each subscriber. Since the output code is entirely unavailable to the subscriber, it can consist simply of the closing of a relay which actuates the decoder. An optional subscriber-identity unit is shown, for reasons which will become clear in a moment.

Actually, when the attachment to a

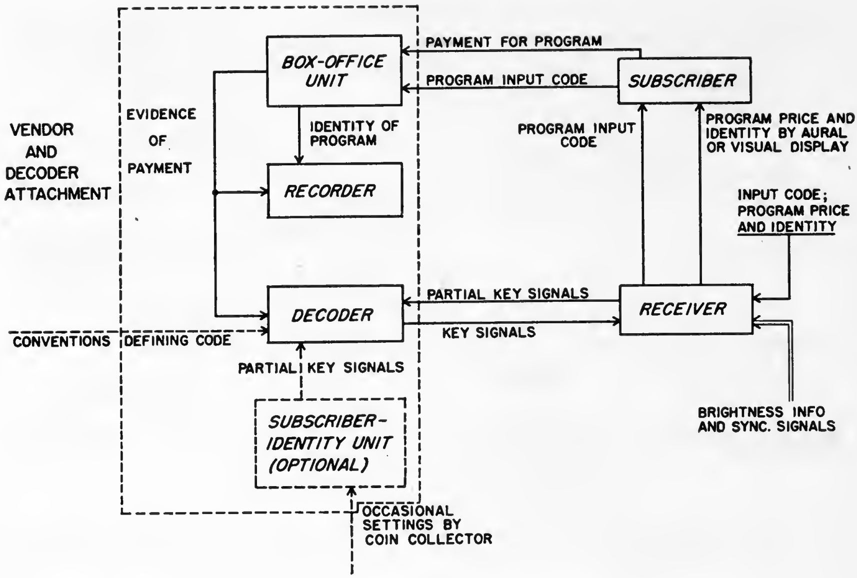


Fig. 7. Coin-operated unit with subscriber intervention; automatic output code.

subscriber's set includes the boxoffice unit and the recorder, as well as the decoder, both the input code and the output code may as well be made automatic. This produces some simplification in the equipment and also represents a system which makes the minimum demands upon its user. The resulting fully automatic coin-operated system is the one used by Telemeter. Its logical organization is shown in Fig. 8.

Price and program-identity information reach the Telemeter attachment directly from the television receiver; the price of the program is displayed visually to the subscriber by the boxoffice unit. Payment of the program price by the subscriber actuates the recorder and the decoder. An optional subscriber-identity unit is shown in connection with this system, as it was in connection with that of Fig. 7.

While the subscriber-identity unit is not needed in either of the last-mentioned systems to guard the integrity of the output code, since this code never appears outside the closed box housing the attachment, such a provision may be useful for the following reason. In any coin-operated system, a collector must periodically call to collect the coins that have been deposited in each home unit. The collector will occasionally find no one home when he calls, and will thus be unable to make a collection. One such failure to collect is tolerable, but two or more such failures lead to the danger that the coinbox will be overfull, or the recording medium used up, or both, before a successful collection is made. We may say parenthetically that this constitutes something of an argument in favor of the remote vendor, which can be placed where a collector can always have access to it. Nevertheless, the subscriber convenience afforded by the system of Fig. 8 seems to us sufficient to overwhelm this apparent advantage of the system shown in Fig. 5.

The difficulty just mentioned can be ameliorated by the use of a subscriber-identity unit, not to identify any par-

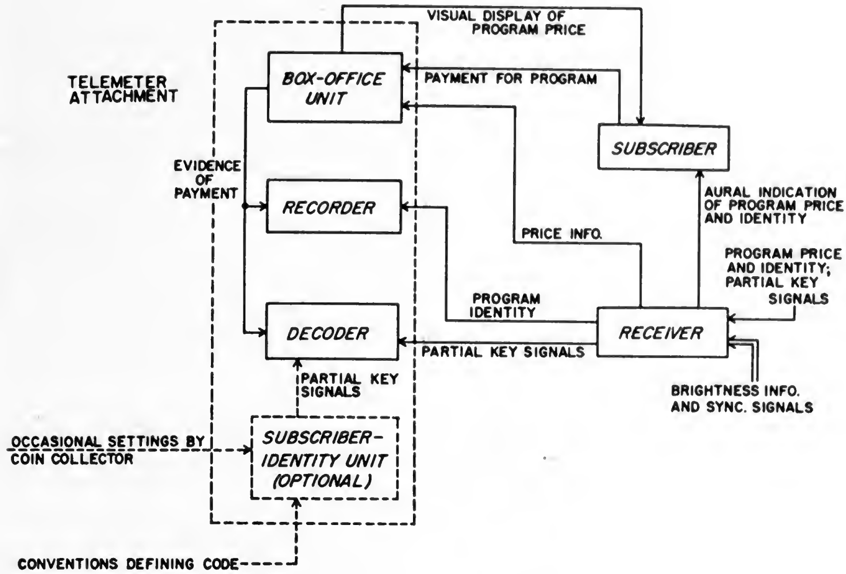


Fig. 8. Telemeter: a fully automatic coin-operated system.

ticular subscriber, but rather to indicate that a sufficiently recent call by a collector has been made. That is, the subscriber-identity unit used in this fashion may be provided with a code sufficiently redundant so that its June setting by the collector will operate satisfactorily during June and July, but not August; the July setting will operate for July and August, but not September, and so on. This will permit one unsuccessful call by the coin collector, but no more than one; if a second unsuccessful call is made, soon thereafter the Telemeter attachment will no longer operate satisfactorily. Occasional settings of the subscriber-identity unit by the coin collector have been indicated in Figs. 4–8 inclusive, to provide for this use of the unit.

Realization of the Telemeter System

It will be apparent from the foregoing discussion that many alternative ways are available for realizing a system of the logical organization and operating features preferred by the International Telemeter Corp. A vigorous program of development is being carried out to determine the optimum detailed design for the system; since this is still in progress, it would be premature to discuss here the details of the encoding, decoding and other means used in the Telemeter system. The authors feel strongly that, as is usual in engineering development, a decision on what had best be done is far more important than the details of how it is to be accomplished; the present paper is therefore devoted to establishing a rational basis for the design of a satisfactory pay-as-you-see television system.

Discussion

Wm. H. Offenhauser, Jr. (*Andre DeBrie of America, Inc.*): I see that the author has used an entirely new set of terms with which this Society is totally unfamiliar. For instance, the terms encode, decode, and secure channel are basic terms that have not appeared previously in our proceedings. Will the author be good enough to add an explicit glossary and bibliography at the end of his paper that will enable readers of our *Journal* to appreciate these new concepts and terms?

Mr. Ridenour: I'll do my best. "Secure" is a word that the Navy uses in a different sense from everybody else. As a matter of fact, the Navy uses it in two senses. One means "to sweep out" and the other means "to keep private"; it's the "to keep private" use of the word that I had in mind. "Encoding and decoding" is just a more precise way of talking about what is often called "scrambling and unscrambling." The latter terms are inappropriate, because, in order to get a picture through a needle's eye the way you must in television, you have to encode the picture in the first place and decode it at the receiver. Thus, all that is meant by "scrambling" is that you use a nonstandard method of coding and decoding. Note also that "nonstandard" is a term which has only a geographical reference; the transmission code that we regard as standard would be quite unintelligible to a French receiver. It is important to the understanding of the subject not to use the terms "scrambling and unscrambling" but to use "coding and decoding" instead.

Axel Jensen (*Bell Telephone Laboratories, Murray Hill, N.J.*): It is quite true that we are in a new field. New ideas are coming out all the time; and when the engineers have new ideas they put words to them — you can't help that. It's up to Societies like SMPTE and IRE later to take a hold of those things and try to standardize some of the terms that are being used. I don't think we should worry too much about it in the very early stages. Eventually those things will get themselves straight.

Anon: I would like to know who owns and maintains the auxiliary equipment for the receiver.

Mr. Ridenour: I'm talking out of turn to answer that question, because this is a matter of policy that will have to be decided after a considerable amount of thought. However, it seems likely that the attachments to people's receivers will have to be managed on the same basis as are telephone instruments. That is, they will have to be, and remain, the property of the operating company, for several reasons. One is that you have to be able to fix them; another is that you must have access to them in order to collect money if it's a coin-operated mechanism, and so on.

Anon: Then in view of that would you say that it is actually cheaper than a telephone line?

Mr. Ridenour: I have asked some telephone engineers about the capital cost represented by a single home telephone installation; it runs well over $350 in the operating company of which I inquired. Now I'm quite sure we can build a satisfactory pay-as-you-see unit for considerably less than that.

Closed-Circuit Video Recording for a Fine Music Program

By W. A. PALMER

The requirement that an experimental series of "Standard Hour" television concerts be released in six markets on 16mm film posed special problems of economics and quality. Closed-circuit special video recording was used incorporating a number of unconventional techniques such as the use of direct-positive "reversal" masters and negative-image release prints. Prescoring was used for all musical numbers and audio procedure made use of $\frac{1}{4}$-in. magnetic tape, 16mm magnetic film, and a direct-positive electro-printed variable-density sound track for final release.

When the Standard Oil Company of California decided to make an experimental television version of "The Standard Hour" musical programs, there were several requirements immediately apparent.

(1) The program would have to be released in six western markets from 16mm film since a network hook-up for these stations was not available.

(2) Audio quality from the 16mm film would have to meet AM radio-network standards so that the radio audience, built up over a period of twenty-five years, would not feel a loss in musical value as a result of the addition of the visuals.

(3) Each program would include a symphony orchestra, a "star" vocalist, a new young "discovery," an instrumental soloist and a ballet number.

(4) Technical procedures followed would have to be efficient and flexible enough to produce the required film material within moderate budget limits.

(5) The caliber of the musical performance and the "stage-craft" used on settings would have to be of the highest order.

After a number of tests and the making of a pilot film, it was decided to use closed-circuit video recording in conjunction with prerecording of the music. In other words, there was to be a combination of television and motion-picture techniques to take advantage of the efficiency of the electronic cameras and still have the advantage of the more flexible handling of musical numbers which has been common in the theatrical motion-picture industry for many years.

Presented on April 28, 1953, at the Society's Convention at Los Angeles by W. A. Palmer, W. A. Palmer Films, Inc., 611 Howard St., San Francisco 5, Calif.
(This paper was received March 27, 1953.)

Fig. 1. General working area; television cameras indicated by arrows.

Or expressed in terminology which has been suggested before: "Electronic Motion Pictures" were to be used.

The programs were produced in "units," each unit supplying several musical numbers which could be spotted on several programs throughout the series. In this way it was possible to have several appearances of a given artist and achieve a great variety in each program. A "unit" involved four days shooting during which enough material for one and a half programs was obtained.

Audio

The production of "The Standard Hour" television programs started with the recording of the musical sound tracks on Ampex $\frac{1}{4}$-in. tape recorders at the ABC San Francisco studios. The $\frac{1}{4}$-in. tape is, of course, not a synchronous medium, but since "prescoring" was to be used, an absolutely synchronous method was not necessary at this stage and the unperforated tape made possible more precise editing.

Two Altec 21B microphones were used, one general pickup for the orchestra and one for the soloists.

In preparing the music, a great deal of advantage was taken of the facility of tape editing, permitting the combination of several takes to get a more nearly perfect performance. With nonperforated magnetic tape, the assembly of parts of a musical number could be accomplished with great precision, since a splice could be made at any desired point, such as between sixteenth notes, without evidence that a cut and splice had been made.

With the completion of the editing of

the tapes, the music was re-recorded to magnetic 16mm perforated film running at 72 fpm. This became the master sound track for all subsequent operations.

At the same time, an additional transfer of the music was made to a 16mm direct-positive photographic sound track while a voice called out numbers at intervals to identify various musical phrases. The photographic track, recorded at the standard 16mm speed of 36 fpm, was used to play back and cue the artists during photography.

Disks were also made and given to the artists so they could rehearse with the recording in privacy prior to the shooting sessions.

Equipment for Photography

During the photography sessions at the Civic Auditorium at Richmond, Calif., four standard RCA image-orthicon camera chains were used as in a regular KGO-ABC "remote" job.

Figure 1 shows the general working area with television cameras (indicated by arrows) on the set in the background and the control and recording equipment in the foreground.

A Houston-Fearless "Academy" crane was used for most shots where a mobile camera was needed. A second camera was mounted on a Fearless baby boom or perambulator and a third was mounted on a RCA pedestal. The fourth camera was mounted on a field tripod, usually located on a high parallel to cover "pattern" shots on ballet sequences.

The usual lens complements were available for all cameras with the addition of a Walker Electro-zoom lens.

All four cameras, with their associated field monitors, were fed through a field-switching unit to a TM5A monitor which had a video-recording camera focused on it.

The 16mm video-recording camera used is of special design with a shutter-optical system combination permitting a shutter-bar free picture to be obtained from the regular 10-in. P4 long-persistence phosphor kinescope.

An optical system in the camera shows an enlarged upright image of the film aperture. Line-up, focus and "picture splice" phasing is done by visual inspection through this optical system and the image on the film may be watched during actual photography.

Picture quality on the monitor was judged by eye with the aid of a Norwood-Bolex exposure meter to set the average light level. The hemisphere light shield was not used on the Norwood meter but the bare cell was held close to the tube face to make a reading.

Lighting equipment was conventional, mostly 2-kw juniors and 750-w "babies," with a few 5-kw seniors and skypans. The great sensitivity of the image orthicons permitted a light level considerably lower than required for regular motion-picture photography even though lenses were usually used at about $f/5.6$.

Photographic Procedure

In photographing the various musical numbers, the photographic sound track with its voiced cue numbers was played back through horns on the set while the artists sang or played along with the track. As an added help in synchronizing, "clicks" were placed in the track wherever there was a drastic change in tempo or a rubato. Audio playback equipment is shown at the extreme right of Fig. 2.

Sometimes, whole musical numbers or at least half of a number would be photographed in one "take," individual scenes being switched or electronically "cut" from the several cameras. At other times one camera position at a time was used and the "cutting" or editing left for the finishing operations in making up the final shows as is the usual technique in regular film making.

As the recording or photographic process was going on, the artists performing in synchrony with their played-back music, the sound track was also being re-

Fig. 2. Arrangement of monitors and controls; audio playback equipment at extreme right.

recorded on a "single system" modulator within the 16mm video-recording camera on the same film that recorded the picture. This track was used as a guide for matching the master sound track in the later operations and served as a sound source during the showing of "rushes" and in the "rough cut" stages of making up complete programs.

Du Pont Type 930 or Eastman Plus X film was used and processed by the reversal method to give a direct-positive master. The commentator and the program pages were also photographed on 16mm reversal film by conventional motion-picture methods.

Make-up of Complete Programs

Since the final release would have to be on 16mm film run on conventional iconoscope chains, experiments were made with different qualities of both positive and negative prints off the 16mm masters with a view to obtaining the best transfer characteristics or gray-scale rendering. The negatives were run on the television film chain with polarity reversal to yield a positive image. These test prints were also put out over the air as an engineering test and observed on home receivers. The most satisfactory transmission resulted from the use of the negative images since the well-known highlight compression characteristics of the iconoscope became compression of the shadows which was actually beneficial to gray-scale rendering. By virtue of the 16mm master reversal film, the negative television release prints could be contact-printed directly without incurring losses in successive steps. The 16mm reversal original thus became the master from which all air release prints were made.

The original reversal film had a sound track recorded alongside the picture as described above and from this composite original, a work print was made by the reversal method to be used for editing. This was accomplished more easily than would have been the case if the usual "double film" technique were used. The usual objections to editing a composite sound-and-picture film did not apply here because the various scenes that were to be joined had an overlap of common sound track of identical modulation. It was therefore only necessary to find the duplicate modulations on two scenes to find the accurate cutting point by reference to either picture or sound track. The fact that the cutting point was 26 frames behind the sound modulation created a minor hazard that had to be kept in mind to avoid errors.

When the final assembly of the entire program was made, combining the various ingredients, stock opening and closing, audience reaction, commentator "on camera," program pages, and institutional message, it was necessary to go to separate films for sound track and picture. However, a shortcut was used to avoid having to run many of the previews in interlock with three sound tracks.

The voice track for the commentator was recorded on 16mm magnetic film at 36 fpm and this was assembled on the same reel interspersed with the photographic-cue track which was used for playback during photographic sessions.

Interlock projections of the entire program could then be made with just one sound track, the combination magnetic-voice and photographic-music track running in synchronism with the picture work print. A special reproducer for this combination sound track was devised so that both magnetic and photographic sound could be reproduced as each type alternately passed the reproducing point.

This combined photomagnetic reel also served as a guide to set up the master music tracks which were double length, that is 72 fpm for maximum fidelity, having a frequency range of 20 to 15,000 cycles. The matching between the combination photomagnetic track and the 72-fpm magnetic track required a synchronizer with a two-to-one gear ratio between sprockets.

Making Final Release Prints

The master 16mm reversal positives were set up in A and B reels for the entire length of the programs since there were many effects, particularly lap-dissolves, in each program. Wherever possible in the musical numbers, each master scene was left in its full length so that the placement of the dissolve could be changed if desired for improved effect after the first answer print or for a different editing in future use of the same material.

Eastman Type 7365 Fine Grain Duplicating Positive was selected for the negative-image release prints which were contact printed from the master positive A and B rolls. The stock had been first prefogged on the picture area only, to a density of 0.2. This served to flatten out the toe of the emulsion characteristic and still further improve shadow detail in the final television transmission.

The picture was printed to have a density range in the negative image from a maximum of 1.5, representing the highest highlight, to 0.2 for the deepest shadow. The film was developed in a D76 negative developer to a gamma of 1.0.

Electrical Printing of Sound Tracks

The sound track was re-recorded or electro-printed to each release print from three sound channels running in synchrony. One channel had the commentator's voice on magnetic 16mm film (the magnetic part of the combination photomagnetic film used in editing). A second channel had all the musical numbers and was the 72-fpm 16mm magnetic film.

The third channel was used for applause tracks.

Each applause track was an authentic complete recording taken from one of "The Standard Hour" radio broadcasts and started with the normal scattered claps, building up to the full volume and gradually subsiding.

The Type 7365 emulsion with its extremely fine grain and yellow dye is most suitable for a high-quality printed sound track but posed some problems in regard to an electrically printed transfer because of the extremely low sensitivity, the emulsion speed being approximately one-ninth the speed of Eastman Type 7302 stock.

Since a satisfactory balance density for a variable-area direct-positive track is very low[1] when applied to medium-contrast positive emulsions, it seemed desirable to use a variable-density track.

The sound track was transferred to the 7365 emulsion by a Western Electric RA1231-C recorder equipped with a special modulator. This was an adaption of the RA294 mirror-type modulator[2,3] with revised optical system designed to give a variable-intensity modulation and compensate for the emulsion characteristic of the 7365 stock yielding a linear-density record in the range between a density of 1.0 and the clear film base. The unusually large mirror of the modulator (6.7 $\times$ 10.0 mm) made possible adequate exposure of the film without overvolting the exposure lamp. Nine decibels of noise reduction was used since the optical compensation for the emulsion characteristic extended through the "toe" to well into the "straight-line" portion. This gave a sound track with a frequency response from 30 to 6000 cycles and with a signal-to-noise ratio of about 40 db, meeting the standards of AM network broadcasting.

Conclusion

The method of closed-circuit video recording described makes possible a very efficient means of good quality television transcription with all the flexibility of live-television camera technique combined with the editing and selection advantages of motion-picture production.

The use of prescoring for a musical program was shown to be entirely practical and eliminated all problems of microphone placement as well as insuring flawless musical performance.

The enthusiasm of the artists for the method was noteworthy. Most volunteered their preference for this combination of television and motion pictures wherein the intense pressure of live-television production and the boredom of painstaking motion-picture production are each tempered to a happy medium.

References

1. John G. Frayne, "Electrical Printing," *Jour. SMPTE, 55:* 590–604, Dec. 1950.
2. R. W. Benfer and G. T. Lorance, "A 200-mil variable-area modulator," *Jour. SMPE, 36:* 331–340, Apr. 1941.
3. W. R. Goehner, "A new mirror light-modulator," *Jour. SMPE, 36:* 488–496, May 1941.

Discussion

Ralph Lovell (NBC, Hollywood, Calif.): Bill, you were very modest about the camera. I think you just mentioned that it was specially constructed. Would you be kind enough to tell us a bit more about how you designed it and from what source you started building this camera?

Mr. Palmer: The camera is still under some development. It might properly be a subject for a future paper. The basic mechanism makes use of parts from a Bell & Howell projector shuttle with a shutter optical system which permits a fade-out fade-in type of action resulting in a "picture splice" which occupies about 30 television lines instead of the usual three or four. To describe it more fully, of course, would require some detail which time does not permit. The unusual feature is that it makes possible the use of a long-persistence white phosphor kinescope. The shutter action can be compensated for any given emulsion to give a shutter-bar free recording.

Mr. Lovell: You said a Bell & Howell movement. Does that indicate a Bell & Howell projector movement?

Mr. Palmer: Projector movement, yes.

Mr. Lovell: Did you also do the same thing with the 35mm movement, make a 35mm camera?

Mr. Palmer: I made a 35mm camera which was used only on the later recordings and because we did not have complete material in 35mm we used it as a protective. It has an accelerated Geneva projector movement with a shutter mechanism similar in principle to the 16mm camera.

Mr. Lovell: I think we all admire you for your ingenuity in making a camera out of a projector. I'd like to ask you, in view of your experience, if you were to initiate another series, what changes would you make? I'm particularly interested — would you continue with the P4 phosphor, or would you try to use the P11 as many other people do?

Mr. Palmer: We would, of course, like to have a high-definition system, since we don't have to be compatible with the 525-line system on a closed circuit. We would probably prefer to continue the use of the P4 phosphor because it allows us to judge the picture quality by eye, a very important factor. In this experimental series we could tell directly from the gray scale apparent on the monitor, the type of recording we would get. The emulsions and the processing chosen were such that we had approximately a unity gamma system through to the home receiver. Actually we did gain a little contrast, but our visual impression on the P4 phosphor gave us a good indication of the final result in the home. Our tests did not indicate that, within the limitations of the 525-line system, we would gain appreciable definition from a P11 tube.

Benjamin Berg (Benjamin Berg Agency, Los Angeles): What is the pulldown time on your shuttle?

Mr. Palmer: The camera shuttle operates with approximately a 30 degree pulldown. Seventy-two degrees are available for shutter action and pulldown so we had a little leeway of some 40 degrees to spread the picture splice.

Anon: I'd like to know how you accomplish this splice of the picture. Is this a conventional shutter or does the density of the shutter itself vary?

Mr. Palmer: It's a little hard to describe in a brief answer, but the shutter is a rotary type with two moving parts which cooperate with and are a part of the optical system. The shutter creates an intensity variation at the film, so that there's no area modulation of the image at the film aperture and the rate at which the shutter opens and closes is variable by adjustments that can be made, similar to the use of shaped masks for direct variable-density recording with a mirror-type modulator.

Engineering Activities

Stereophonic Sound

A major revolution is quietly taking place in the sound end of the motion-picture industry. Stereophonic sound has made its "debut," has been well accepted and is apparently here to stay, but its entry has been somewhat obscured by the simultaneous and very dramatic introduction of 3-D and wide screens.

All that glitters is not gold and all multiple-track sound recording is not stereophonic, although often highly touted as such. True stereo (auditory perspective of lateral location and depth) requires the use not only of multiple recording channels but properly spaced microphones as well. Pseudo-stereo may employ one mike in the studio whose output is later re-recorded on one or more of the multiple tracks to simulate a stereophonic effect. The resulting sound illusion on the screen may, however, if astutely done, bear a marked resemblance to the original sound scene and if it is, the audience will probably feel a sense of sound perspective.

Magnetic recording (the stereo sound medium) was first used in motion picture studios in 1947 and was confined to original recording from which a photographic track was re-recorded for release. The rapid adoption of the magnetic medium led early to a need for industry standards. The Society's Sound Committee took the initiative here and after much discussion and some delay a 35mm, 3-track, magnetic proposal was approved as an American Standard (PH22.86-1953 in the May 1953 *Journal*).

The development of this standard greatly furthered the use of stereo sound in the theater, for it provided a ready vehicle for both the studios and equipment manufacturers to rapidly exploit this advance in sound realism.

However, in one respect this may be characterized as "one step forward and two steps back" for, as they were in the first days of sound, picture and sound are again on separate media. The separate magnetic 3-track reproducers and selsyn sync control systems now used in stereo sound are certainly a far cry from the phonograph and disk record used in the twenties. Nonetheless, they are looked upon as an added complexity in the projection booth, and at that, but a stopgap measure. Just how soon composite picture and stereo sound will be generally available is anyone's guess at this point, but it certainly looms as an early eventuality. The August 13, 1953, demonstration of CinemaScope's composite picture and stereo sound undoubtedly lends weight to the notion that the single-film system is, at any rate, technically feasible right now.

This places the exhibitor in somewhat of a spot. Should he buy dual-film stereo sound equipment now or hold off until single-film features and equipment are available?

It would appear that the exhibitor would have to consider three factors before making his decision:

(1) the effect of 3-D sound on boxoffice receipts,

(2) the number of dual-film features scheduled for production and release, i.e., pay-off time,

(3) amount of first equipment which could be converted for use with final equipment.

Estimates on the latter two factors are available. John Hilliard, Chairman of the Sound Committee, conducted an informal survey of the Hollywood studios the first week of August which revealed that roughly 40 dual-film features are in production or in the planning stage. A recent conference of East Coast engineers and exhibitors estimated that about 75% of initial investment in stereo sound equipment (amplifiers, speakers, etc.) could be used directly in a later conversion to a single-film system.

Status of the Theater-Screen Survey

The survey initiated by the Theater Engineering Committee in May 1953 was described in the preceding *Journal.* At this writing some eight thousand questionnaires have been distributed with but 250 returned. At least twice this number of returns are required before a statistical analysis can be made. Since this survey can be an important factor in standardizing a new aspect ratio, exhibitors are being urged to request, fill out and return these questionnaires.

Standards

The new is based on the old: despite its active participation in the new developments, the Society is continuing unabated its usual standards activity. To this end, the Board of Governors, at its July meeting, approved 11 reaffirmations and two revisions of existing standards:

Reaffirmations: PH22.27, -.37, -.46, -.47, -.60, -.62, -.65, -.66, -.67, -.69 and -.70.

Revisions: PH22.43 and -.44.

These standards have since been submitted to the Photographic Standards Board of the ASA and will in all likelihood be given formal ASA approval within the next two months.

In addition the following projects are in the works:

Film Projection Practice Committee: withdrawal or revision of American Standard PH22.28-1946, Projection Rooms and Lenses for Theater, SMPTE 628.

16mm and 8mm Motion Pictures Committee: withdrawal of American Standard PH22.54, 16mm Travel Ghost Test Film, SMPTE 611; and revision of two American Standards — PH22.15, 16mm Film Perforated One Edge — Usage in Camera, SMPTE 518, 614; and PH22.16, 16mm Film Perforated One Edge — Usage in Projector, SMPTE 519, 615.

Sound Committee: four proposed American Standards — SMPTE 617, 35mm 3-Track Magnetic Flutter Test Film; SMPTE 618, Azimuth Alignment Test Film for 35mm 3-Track Film With Magnetic Coating; PH22.88, Dimensions for Magnetic Coating on 8mm Motion Picture Film, SMPTE 624; and SMPTE 626, Magnetic Coating on 16mm Film Perforated Two Edges. And revision of three American Standards — PH22.42, 16mm Sound Focusing Test Film, SMPTE 622; PH22.45, 16mm 400 Cycle Signal Level Test Film, SMPTE 623; and PH22.57, 16mm Buzz Track Test Film, SMPTE 621.

Copies of any of the above proposals are available upon request.—*Henry Kogel,* Staff Engineer.

Southwest Subsection Meeting

A successful meeting of the Subsection was held on May 20 at the Beard & Stone Electric Company auditorium in Dallas. The membership of the North Texas section of COMPO were invited to meet with us to hear Herbert Barnett's speech to the Western Pennsylvania exhibitors convention. However, COMPO had a benefit barbecue for the Waco tornado victims the same evening so we had only two guests.

There were 18 people present including Hervey Gardenhire who has come about 300 miles from O'Donnell, Texas, for every meeting we have had except the one of last November when the roads were too "iced-up" for travel; also there were members from San Antonio and Austin.

Mr. Barnett's paper was read by program chairman I. L. Miller, and subsection chairman Bruce Howard read W. A. Palmer's Los Angeles convention paper, "Closed Circuit Video Recording for a Fine Music Program."

There was some discussion on the type of meetings held thus far by the Subsection, and a committee composed of Hugh Jamieson, Sr., J. Oakleigh Hill and A. B. Chapman was appointed to draft a letter to the Southwest Subsection membership, asking their preference as to program material, meeting places and choices of days of the week. It was hoped that information in response to this inquiry would be on hand in time to be of use in planning the first Fall meeting.—*Hugh Jamieson, Jr.,* Secretary-Treasurer, Southwest Subsection, 3825 Bryan St., Dallas 4, Texas.

Central Section Meetings

Following the May 21 meeting described in the June *Journal*, the Central Section soon held two more meetings on May 27 and June 11, making an unprecedented total of three meetings taking place in as many weeks. The May 27 meeting, held at the Western Society of Engineers, Chicago, drew about 220 for an evening of stereoscopy. Those attending saw what was described as the first industrial 3-D film to be made — *Packaging the Third Dimension*, by Academy Film Productions Inc., Chicago, dealing with the manufacture of corrugated cartons. Guests from the Northern Illinois College of Optometry were also on hand at this meeting to hear an interesting and provocative paper on "Beneficial Effects of Properly Produced, Projected and Viewed Stereoscopic Motion Pictures on Binocular Visual Performance," by R. A. Sherman, of Bausch & Lomb Optical Co., Rochester, N.Y. This paper had already attracted considerable attention at the Los Angeles Convention, where it was first presented. It was plain from the success of this meeting that 3-D is a prime attention-getter, and it is likely that additional papers on this subject will be presented in the Fall.

The meeting on June 11 was held at the Geo. W. Colburn Laboratory, Inc., Chicago. Mr. Colburn gave a report describing the progress that has been accomplished in applying the SMPTE proposed standard for printer light cuing of 16mm motion-picture films; and a paper by Edward Yuhl on the RYB "Wireless Mike," a lightweight transmitting microphone, was presented by Henry Ushijima. About 125 attended this meeting, which concluded with a tour of the Colburn Laboratory facilities, and refreshments.

Tentative meeting dates for the Fall Season have been set for September 11, at Dayton, Ohio, and October 15, November 12 and December 10, at Chicago.—*James L. Wassell*, Secretary-Treasurer, Central Section, 247 E. Ontario St., Chicago 11.

Pacific Coast Section Meetings

Under the direction of Herbert Farmer, Faculty Advisor and Acting Head of the Department, and Kenneth Miura, Chairman of the Student Section, SMPTE, the fifth meeting of the Pacific Coast Section of the SMPTE was held at the Department of Cinema, University of Southern California, on May 19, 1953.

Society members and guests had dinner on the campus, followed by a presentation of short papers and demonstrations of motion-picture productions and special projects presently under way at the campus.

The program opened with a recent short motion-picture production made by the Department of Cinema. Following this, Richard Polister spoke on "The Scope of Motion-Picture Production in Colleges and Universities," reviewing the technical progress of production units in various universities and colleges throughout the country. Nicholas Rose, Director of Research in the Department, then spoke on "Analysis of Audience Reactions and Behaviors." He described systematic techniques for studying audience behavior in the evaluation of film effectiveness, and explained their development in the Research Division of the Cinema Department. A film demonstration of the various processes used was shown. "Uses of Silhouette Special Effects" was the subject explored by William Mehring, Instructor in Cinema, and covered a new motion-picture technique which has become a worthwhile classroom tool in the study of directional problems. A review of the production activities of the Department was given by Wilbur T. Blume, Director of Productions, with accompanying screen excerpts from recent films. The formal meeting was followed by an open house of the Department of Cinema.

For the June meeting, the last before the summer vacation, the Pacific Coast Section enjoyed an evening at NBC, Burbank, on June 23, 1953. NBC's new and modern plant is located on a 48-acre property which provides considerable space for future expansion. Two large audience studios are already completed, and there are two large rehearsal halls and a modern Production Services building containing several interesting innovations. Due to the broad interest of this program, members were invited to bring guests, resulting in the second largest meeting of the year, with 460 in attendance.

A. H. Saxton, Technical Network Operations Manager, welcomed the group and exhibited a 35mm kinescope recording. "A New 35mm Single Film System Kinescope Recording Camera" was described by Ralph E. Lovell, Kinescope Recording Supervisor. The first production model was shown, containing many interesting features. Marvyn S. Adams, Technical Operations Supervisor, spoke on "Technical Operating Facilities of the Burbank Studios," describing many of the special interlocking, automatic and interconnecting features which have been provided to meet present needs and to provide maximum flexibility for future requirements. A large screen theater TV unit for audience viewing was demonstrated. Special features of "Staging Services at the Burbank Studios" were described by R. Don Thompson, Manager of Television Staging Operations.

A tour of the entire NBC installation in Burbank followed the formal program.—*Philip G. Caldwell*, ABC Television Center, Hollywood 27, Calif.

Photographic Technology and BS Degrees

The Department of Photographic Technology at the Rochester Institute of Technology has built up a considerable reputation since it was founded in 1930, and at the present time stands high among schools of this kind. Two-year courses, including Processes of Color Photography are available, leading to the Associate in Applied Science degree. The New York State Board of Regents has approved plans which the Institute expects to have in effect so that students entering this Fall can begin study toward a bachelorate degree. Of about 100 students graduated yearly, several begin a career in some phase of motion-picture work. So far there have been no specific courses in motion-picture photography available, but tentative plans are being made to incorporate a major course in this field a year from now.

Journals in Two Parts

Part II of this *Journal* has the complete roster of the papers from the Screen Brightness Symposium held at the recent Los Angeles Convention. Reprint copies of this symposium are available from Society headquarters at $1.00 each.

Next month's *Journal* will also have a Part II, comprised of all those Los Angeles Convention manuscripts now available and having to do with stereophonic principles and equipment. Also included are three articles about basic development and the principles of auditory perspective, reprinted from a symposium in the *Bell System Technical Journal* for April 1934 and *Electrical Engineering* for January 1934. Single copies of this material are expected to be available at $1.00 each.

Book Reviews

The Science of Color

Committee on Colorimetry of the Optical Society of America, L. A. Jones, Chairman. Published (1953) by Thomas Y. Crowell, 342 Fourth Ave., New York 16. i-xiii + 340 pp. + 22 pp. references + 23 pp. glossary-index. 102 color plates + 40 tables + 102 illus. 7 × 10 in. Price $7.00.

The information contained in *The Science of Color* is background information which the good color technologist in any field should have. For this reason, the book is highly recommended for graduate study and research work.

The Science of Color can be divided roughly into three general sections: physical, psychophysical and psychological. Two chapters are devoted to physical information. One discusses radiant energy and its measurement and describes the behavior of light as it strikes matter and is transmitted or absorbed. This type of information is useful in understanding how light is modified by selected absorption and thereby becomes colored. Another chapter is devoted to the anatomy of the eye and physiology of color vision. This chapter gives a description of the construction of the eye and its various component parts and is useful in understanding the perception of color.

The psychophysical aspects of color involve the measurement of the color properties of an object and of light in order to determine the color effect the light will have upon an observer. Three chapters are devoted to this extensive subject. It is by the methods of measurement described in this section that the engineer is able to evaluate the color of objects he fabricates.

In the psychological section, one chapter is devoted to the sensory aspects of color and discusses such things as after-images and color discrimination. Among many other interesting facts it is pointed out that color discrimination in children improves rapidly up to the age of 25 years and is followed by a gradual falling off which becomes more pronounced around the age of 65. Another chapter is devoted to the perceptual and affective aspects of color. One of the many subjects discussed here is the mode of appearance, and we learn for instance that when an artist partially closes his eyes to evaluate color perception better he is endeavoring to separate color from object perception and is in effect changing the mode of appearance from a surface color to a film color. Also in this chapter we learn that in motion pictures the "mood" of a story can be maintained for a long sequence simply by continuing the dominant color.

The book is unique in that it includes a glossary index in which a large number of color terms are defined and reference given to sections of the book where the subject is discussed.

The technologist or engineer who in his daily work is handling materials to produce pleasing colors may be disappointed in the book in that it does not deal with the technology of color. When an engineer thinks of color, he is very likely to think of the limited aspects of producing colored films, colored television screens or colored objects—which is color technology. Actually the science of color embraces a large number of fields and consists of all knowledge concerning the production of color stimuli and their visual perception. The book quite properly includes all these aspects. If the engineer reads this book with the idea of getting background knowledge in order to understand better many of the color phenomena which arise in his daily work, he will find it well worth while.—*E. I. Stearns*, American Cyanamid Co., Calco Chemical Div., Bound Brook, N.J.

"Color"

From Germany comes an announcement of a new journal entitled *Color*, to be concerned with all aspects of color photography, colored light, color vision and its testing and color sensitometry. The Board of Editors includes some of the foremost authorities in Germany, such as Manfred Richter, E. Engelking, A. Kohlrausch, S. Rösch and J. Eggert. The journal is to appear in occasional numbers at 7.80 German marks per number. Full information can be obtained from the Verlag für angewandte Wissenschaften G.m.b.H., Rheinstrasse 79, Wiesbaden.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 Membership Directory.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Arthur, James K., Northwestern University **Mail:** 8916 Skokie Blvd., Skokie, Ill. (S)

Bernstein, Robert, Television Engineer, American Broadcasting Co. **Mail:** 683 Bradford St., Brooklyn 7, N.Y. (A)

Brossok, William C., Westrex Corp. **Mail:** 160 Beach St., Staten Island 4, N.Y. (A)

Buck, Peter J., Production Engineering Manager, Westrex Corp. **Mail:** 180 Prospect St., East Orange, N.J. (A)

Budd, E. R., Assistant Manager, B. F. Shearer Co., 1964 South Vermont Ave., Los Angeles, Calif. (A)

Burton, Don, Radio and Television Station Manager, Tri-City Radio Corp., P.O. Box 271, Muncie, Ind. (M)

Cahill, Don, Producer, Photographer. **Mail:** 5707 W. Lake St., Maywood, Ill. (A)

Chavvaria N., Alvaro, Apartado #1923, San Jose, Costa Rica, Central America. (A)

Chesnes, Albert A., Manager, Television Operations, Paramount Pictures Corp. **Mail:** 45-21—76 St., Elmhurst, N.Y. (M)

Clay, John P., Engineering Supervisor, WSAZ-TV. **Mail:** 3034 Third Ave., Huntington, W. Va. (M)

Conviser, Benjamin S., Executive, American Theatre Supply Corp., 78 Broadway, Boston 16, Mass. (M)

Cook, Lewis Clark, Technical Director, Central Illinois Telefilms, 810 North Sheridan Rd., Peoria, Ill. (M)

Cornberg, Sol, Supervisor of Plant and Facilities Development, National Broadcasting Co., Inc., 30 Rockefeller Plaza, New York, N.Y. (M)

Edison, Edward, Television Engineer, National Broadcasting Co. **Mail:** 329 Sycamore Rd., Santa Monica, Calif. (M)

Elliott, Lt. Col. Robert D., Motion-Picture Technical Staff Officer, U.S. Air Force. **Mail:** 12242 Magnolia Blvd., North Hollywood, Calif. (M)

Evans, William E., Jr., Television Research Engineer, Stanford Research Institute, Stanford, Calif. (M)

Fisher, Frank H., General Manager, J. Arthur Rank Film Distributor (Canada) Ltd., 277 Victoria St., Toronto, Canada. (A)

Goodman, R. Irwin, University of California at Los Angeles. **Mail:** 737 Burchett St., Glendale 2, Calif. (S)

Graziano, Peter S., Motion-Picture Printer Operator, Cinecolor Corp. **Mail:** 3013 West Via Ceizro, Montebello, Calif. (A)

Gregory, Howard P., Vice-President, Wilbur Machine Co., Inc., 50 Wall St., Binghamton, N.Y. (M)

Grube, Wolfgang Otto, Project Engineer, Research and Development Division, Mergenthaler Linotype Co. **Mail:** 130 Harcourt Ave., Bergenfield, N.J. (A)

Hagenau, Scott N., Assistant Chief Engineer, WSBT, WSBT-TV, 225 West Colfax Ave., South Bend 26, Ind. (A)

Hansen, William E., Film Technician, Acme Film Laboratories. **Mail:** 3369 Rowena Ave., Los Angeles 27, Calif. (M)

Hoyle, Peter I., Sound Engineer, Information Services Dept., Gold Coast Film Unit, P.O. Box 745, Accra, Gold Coast, West Africa. (A)

Janetis, Michael, Motion-Picture Cameraman. **Mail:** 100 W. 80 St., New York, N.Y. (A)

Jordan, Thomas E., Jr., Senior Motion-Picture Specialist, U.S. Air Force. **Mail:** 545 South St., Glendale 2, Calif. (A)

Kane, Henry S., President, North American Screw Products Co., Inc. **Mail:** 1732 North California Ave., Chicago, Ill. (M)

Kavlin, Marcos, Kodak Dealer, Casilla 500, La Paz, Bolivia. (A)

Kubicka, Heinz F., Chief Engineer, Television Advertising Association, Inc. **Mail:** 530 Riverside Dr., Apt. 1C, New York 27, N.Y. (A)

Leiby, Alden M., Chief Engineer, Franklin Electronics, Inc. **Mail:** 7926 Burholme Ave., Philadelphia 11, Pa. (M)

Levy, George M., Jr., Photo Patrol, Cine Speed, Inc., Roosevelt Raceway, Westbury, Long Island, N.Y. (M)

Locanthi, Bart N., Research Engineer, Acoustical Consultant, Cal-Tech, J. B. Lansing Sound Co. **Mail:** 2552 Boulder Rd., Altadena, Calif. (M)

Morrison, James C., University of California at Los Angeles. **Mail:** 6948 Cedros Ave., Van Nuys, Calif. (S)

Morrison, William A., Sales, Magnetic Sound Products, Reeves Soundcraft Corp., 10 E. 52 St., New York 22, N.Y. (A)

Muncheryan, Hrand M., Staff Physicist, Aerojet Engineering Co. **Mail:** 1202 Sesmas St., Duarte, Calif. (A)

Nicholson, Elwood J., First Cameraman, Director of Photography, Cinematic Production Service, 1123 Lillian Way, Hollywood Calif. (M)

Niles, Fred A., Vice-President, Director of Motion-Picture-Television Division, Kling Studios, Inc., 601 North Fairbanks Ct., Chicago 11, Ill. (M)

Norman, J. E., West Coast Manager, De Vry Corp., 5121 Sunset Blvd., Hollywood 27, Calif. (M)

Orrett, William S., Radio Engineer, International Productions, Ltd. **Mail:** Wexford P.O., Ontario, Canada. (A)

Palys, Frank, Photo Supplies, 207 Third St., Elizabeth, N.J. (A)

Patterson, Stanley, President and Partner, Pampa Electronics Sales Corp. **Mail:** 1380 Dermond Rd., Drexel Hill, Pa. (M)

Regal, Frank R., Film Technician, Warner Bros. Studio. **Mail:** 302½ Hollywood Way, Burbank, Calif. (A)

Ridinger, H. J., Jr., Television Technician, KLAC-TV. **Mail:** 11808 South Ruthelen, Los Angeles 47, Calif. (A)

Ronson, Harry A., Television Workshop of New York. **Mail:** 1510 E. Fourth St., Brooklyn 30, N.Y. (S)

Salas-Porras, Francisco, Assistant Manager, Azteca Films, Inc. **Mail:** 6102 Flores Ave., Los Angeles 56, Calif. (A)

Saxon, Spencer D., Motion-Picture Photographer, Audio-Visual Center, Syracuse University, Collendale at Lancaster, Syracuse 10, N.Y. (A)

Scales, John W., Chief Projectionist, Columbia Pictures Corp. **Mail:** 11622 Hamlin St., North Hollywood, Calif. (M)

Schwab, Don R., Film Producer, Sportsvision, Inc. **Mail:** 550 Veteran Ave., Los Angeles 24, Calif. (M)

Signaigo, Frank K., Research Director, E.I. du Pont de Nemours & Co., Photo Products Dept., Wilmington, Del. (M)

Snyder, J. Earl, Sound Mixer, Ryder Sound Service. **Mail:** 4755 Columbus Ave., Sherman Oaks, Calif. (M)

Stableford, John, Projection Equipment Manufacturer. **Mail:** 45 Latimer Rd., London W.11, England. (A)

Stickling, John H., Motion-Picture Projectionist, Starview Outdoor Theater, Inc. **Mail:** R.R. #2, Box 74, Dundee, Ill. (M)

Stratford, John, Executive Motion-Picture and Television Producer, Splendid Films, Inc. **Mail:** 2239 Savannah Ter., S.E., Washington 20, D.C. (A)

Tami, Joseph, Jr., University of California at Los Angeles. **Mail:** 3919 Third Ave., Los Angeles 8, Calif. (S)

Tate, John C., Printer Foreman, Acme Film Laboratories. **Mail:** 12208 Oxnard St., North Hollywood, Calif. (A)

Wallin, Walter, Optical Physicist. **Mail:** 20226 Arminta St., Canoga Park, Calif. (A)

White, Roy A., Television Engineer, Studio Supervisor, Paramount Television Productions, Inc. **Mail:** 913 North Frederic, Burbank, Calif. (A)

Wiener, Alan J., Manager, Visual Advertising Associates TV. **Mail:** 24 Lyons St., New Britain, Conn. (A)

Wright, Walter W., Design Engineer. **Mail:** 1822 Essex Ave., Linden, N.J. (A)

Young, Blanche, University of Southern California. **Mail:** 711¾ W. 35 Pl., Los Angeles 7, Calif. (S)

CHANGES IN GRADE

Buxbaum, Morton L., (S) to (A)
Clarke, Charles G., (A) to (M)
Dodge, Glenn T., (S) to (A)
Moorhouse, Anson C., (A) to (M)
Sarber, Harry, (A) to (M)
Sloan, Melvin, (S) to (A)
Woolsey, Ralph A., (A) to (M)

DECEASED

Harvey, Douglas G., University of Southern California. **Mail:** 1846 South Cochran Pl., Los Angeles 19, Calif. (S)

Oakhill, Frederic E., President, Prismacolor Pictures, Inc. **Mail:** 711 Linden Ave., Wilmette, Ill. (M)

SMPTE Lapel Pins

The Society has available for mailing its gold and blue enamel lapel pin, with a screw back. The pin is a ½-in. reproduction of the Society symbol — the film, sprocket and television tube — which appears on the *Journal* cover. The price of the pin is $4.00, including Federal Tax; in New York City, add 3% sales tax.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal.*

Chemical Corner

Edited by Irving M. Ewig for the Society's Laboratory Practice Committee. Suggestions should be sent to Society headquarters marked for the attention of Mr. Ewig. Neither the Society nor the Editor assumes any responsibility for the validity of the statements contained in this column. They are intended as suggestions for further investigation by interested persons.

German Developing Machines The Union Color Developing Machine constructed for both the new negative/positive color processes and black-and-white is a low-cost machine reported capable of turning out twice the footage of our previous machines. Of duplex design, it can be had with 35mm or 16mm on each side or a combination of these. The drive mechanism is at the bottom and the film is transported by friction rollers. The tanks are lined with a thermoplastic material which is completely noncorrosive in the strongest bleach. The temperature of the solutions is controlled by heat exchangers located in the tanks themselves. The agents are Movie Technicians, 55 Poplar Ave., Hackensack, N. J.

Regeneration of Ferricyanide Bleach Baths U.S. Patent 2,611,699 makes claims for another scheme of the conversion by bromine of ferrocyanide back to the active ferricyanide and also supplies additional bromide in the process. The bromine is added in the required quantity as determined by analysis in the form of a hypobromite or of a bromate.

Hazardous Chemicals in Photography With the recent increase in the chemical activity in the motion-picture laboratory arising from color, 3-D and other new processes, a timely article in the *British Journal of Photography*, October 8, 1952, pp. 380–81, deals with dangerous chemicals that may be encountered in photography. Allergic reaction to chrome salts, developing and cleaning agents, especially the chlorinated ones near a glowing cigaret or flame hazards are mentioned along with other dangers which may be expected in experimental laboratories and darkrooms.

Sepia Tone Control Claims are made in U.S. Patent 2,607,686 for controlling the coldness of sepia tones by the adjustment of the bromide content of the developer. The higher the bromide the colder the tone.

Another Approach to Silver Recovery and Fixer Rejuvenation At the Naval Air Station at Anacostia, D.C., exhausted fixer is collected in a storage tank. When the liquid reaches a certain level an electrolytic silver recovery unit is automatically started. Ten stainless-steel cathodes collect the silver while the treated bath, which is rejuvenated at the rate of 90 gal/hr, is tested, readjusted and mixed with 20% fresh solution. A more complete description of this process is given in *American Photography*, December 1952, p. 12.

A Transparent Pipe Mills 111 is a transparent plastic pipe of cellulose acetate butyrate ranging in size from ½ to 4 in. It permits observation of processes and is highly resistant to attack by chemical solutions. Pipe sections are joined by a solvent cement that produces a leakproof homogeneous bond. No threading or special tools are required and it is cut with a hand saw. Setups may be dismantled and all components used repeatedly. The tubing is tough, shatterproof and requires a minimum of support. The manufacturer is Elmer E. Mills Corp., 2930 North Ashland Ave., Chicago 13, Ill.

A Greaseless Grease "Molynanul" is a molybdenum disulfide enamel which can be brushed or sprayed on any surface to give a very thin film lubricant. It puts a lustrous, hard, greasy-feeling but clean, coating from a fifth to a half-thousandth of an inch thick. Except in extreme cases normal clearances need not be disturbed as the final thickness is no greater than the allowance for oil. Its applications are numerous and might be investigated as a lubricant for motion-picture film. The manufacturer is The Lackrey Company, Southampton, N.Y.

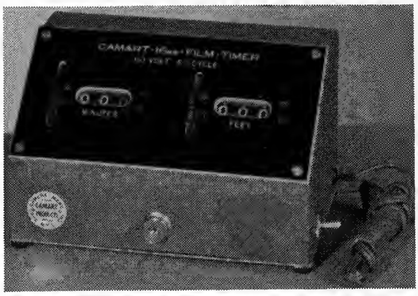
New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.

The first commercial production in the U.S. of optical-quality fused quartz intended for use in electronic computers, scanners, etc., is announced by Hanovia Chemical & Mfg. Co. The new quartz will be manufactured by Optosil Inc., Hillside, N.J., a newly formed subsidiary of Hanovia.

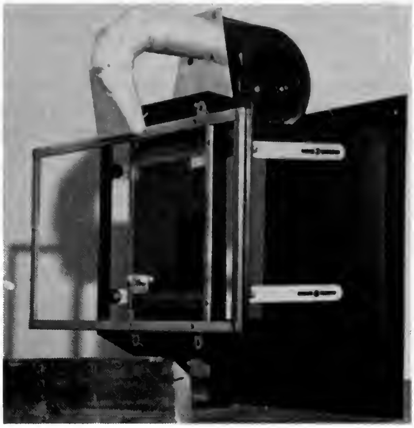
A major electronic application of Optosil quartz will be for ultrasonic solid delay lines whose function is to create a time delay of electrical impulses for predetermined periods. In such delay lines, the electromagnetic waves are first converted to ultrasonic waves through a piezoelectric transducer. These amplitude-modulated ultrasonic waves are then passed through a quartz medium, after which they are reconverted to an electrical signal whose modulation is identical with the input. Because of the ratio of 100,000:1 between the velocity of the electromagnetic waves and that of the sonic waves in the quartz medium, a significant time delay results. Relatively long delay periods in a small space can be produced by the use of multiple reflection paths (in two or three dimensions) within the quartz medium.

In the optical field, the new company will be prepared to supply the requirements of a variety of laboratory and commercial needs to which optical-quality fused quartz is suited. Among these are precision lenses, optical flats, projection lenses which operate under conditions of great heat and thermal shock, and any optical equipment which must transmit a high degree of ultraviolet radiation.



An electric film timer, tradenamed the Camart, has been designed and marketed by The Camera Mart, Inc., 1845 Broadway, New York 23, N.Y., for use in motion-picture editing, dubbing, narration, script timing and commenting. The unit will read elapsed time in minutes and tenths and will record total footage for 16mm or 35mm motion-picture film. The timer may be wired to the projector or recorder to start automatically, or may be used independently. It may be started and stopped any number of times, and the time or footage indicators may be reset separately. The mechanism is removable from the chassis for mounting in a rack assembly. Dimensions are $4\frac{1}{2}$ in. high by $4\frac{1}{2}$ in. wide by $7\frac{1}{2}$ in. long, weight 4 lb. A combination timer for either 16mm or 35mm footage with time indicator is priced at \$125. A combination 16mm and 35mm footage counter is also priced at \$125. A single 16mm or 35mm footage counter sells for \$75.

A new filter alignment and cooling mechanism has just been put into production by the Drive-In Theatre Mfg. Co., Division of DIT-MCO, Inc., 505 W. Ninth St., Kansas City 5, Mo. The metal housing is designed to be mounted permanently at the porthole. The dimensions of the entering and leaving sides are sufficient to accept the wide projection beam of CinemaScope and Cinerama. The depth is such that it will not interfere with the projector, even at extreme angles, or with large magazines. The top plate of the housing is flat for blower mounting, and the bottom plate is sloped down at a 25° angle, to accept projection beams up to this angle. Where the need is for a greater pitch, any angle can be made. The blower has a capacity of 100 cfm with a 3050-rpm motor. The duct and spreader are metal, and the spreader is designed to distribute air over the entire surface of the filter. The framing mechanism is designed so that, after proper



alignment of the filter, it can be permanently locked to that alignment. The eight adjustments for the filter are in and out; up and down; top or bottom in and out at angles; right and left angles to horizontal.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, and there is no charge to the member.

Positions Wanted

Experienced motion-picture production man desires connection with film company as producer-director or production manager. During past 12 yrs. experience includes directing, photographing, editing, recording and processing half-million feet finished film, including educational films, industrials, TV spots, package shows for TV and experimental films. University graduate, married, twenty-nine years old; good references. Locate anywhere continental U.S. Write Victor Duncan, 8715 Rexford Drive, Dallas 9, Tex.

Film Production/Use: Experienced in writing, directing, editing, photography; currently in charge of public relations, sales and training film production for industrial organization. Solid film and TV background, capable administrator, creative ability, degree. References and résumé upon request. Write FPF, Room 704, 342 Madison Ave.. New York 17, N.Y.

Positions Available

Wanted: Optical Engineer for permanent position with manufacturer of a wide variety of optics including camera objectives, projector, microscope and telescope optics, etc. Position involves design, development and production engineering. Send résumé of training and experience to Simpson Optical Mfg. Co., 3200 W. Carroll Ave., Chicago 24, Ill.

Wanted: Personnel to fill the 4 classifications listed below, by the Employment Office, Atten: EWACER, Wright-Patterson Air Force Base, Ohio:

Film Editor, GS-9: Must have 5 yrs. experience in one or more phases of motion-picture production. Experience must include at least 1½ yrs. motion-picture film editing with responsibility for synchronization of picture, narration, dialogue, background music, sound effects, titles, etc. $5060 yr.

Photographic Processing Technician (Color) GS-7: 6 yrs. progressively responsible experience in motion-picture photography and/or photographic laboratory work, involving essential operation of film processing. Eighteen months of this experience must have involved processing of color film. $4205 yr.

Photographic Processing Technician (Black-and-White) GS-7: 6 yrs. progressively responsible experience in motion-picture photography and/or photographic laboratory work, involving essential operation of film processing. $4205 yr.

Photographic Processing Technician (Black-and-White) GS-5: 2½ yrs. progressively responsible experience in motion-picture photography and/or photographic laboratory work, involving essential operation of film processing. $3410 yr.

Meetings

Society of Motion Picture and Television Engineers, Central Section Meeting, Sept. 11 (tentative), WLW-D, Dayton, Ohio

Illuminating Engineering Society, National Technical Conference, Sept. 14–18, Hotel Commodore, New York, N.Y.

The Royal Photographic Society's Centenary, International Conference on the Science and Applications of Photography, Sept. 19–25, London, England

National Electronics Conference, 9th Annual Conference, Sept. 28–30, Hotel Sherman, Chicago

74th Semiannual Convention of the SMPTE, Oct. 5–9, Hotel Statler, New York

Audio Engineering Society, Fifth Annual Convention, Oct. 14–17, Hotel New Yorker, New York, N.Y.

Society of Motion Picture and Television Engineers, Central Section Meeting, Oct. 15 (tentative), Chicago, Ill.

Theatre Equipment and Supply Manufacturers' Association Convention (in conjunction with Theatre Equipment Dealers' Association and Theatre Owners of America), Oct. 31–Nov. 4, Conrad Hilton Hotel, Chicago, Ill.

Theatre Owners of America, Annual Convention and Trade Show, Nov. 1–5, Chicago, Ill.

National Electrical Manufacturers Association, Nov. 9–12, Haddon Hall Hotel, Atlantic City, N.J.

Society of Motion Picture and Television Engineers, Central Section Meeting, Nov. 12 (tentative), Chicago, Ill.

The American Society of Mechanical Engineers, Annual Meeting, Nov. 29–Dec. 4, Statler Hotel, N.Y.

Society of Motion Picture and Television Engineers, Central Section Meeting, Dec. 10 (tentative), Chicago, Ill.

American Institute of Electrical Engineers, Winter General Meeting, Jan. 18–22, 1954, New York

National Electrical Manufacturers Assn., Mar. 8–11, 1954, Edgewater Beach Hotel, Chicago, Ill.

Optical Society of America, Mar. 25–27, 1954, New York

75th Semiannual Convention of the SMPTE, May 3–7, 1954, Hotel Statler, Washington

76th Semiannual Convention of the SMPTE, Oct. 18–22, 1954 (next year), Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955, Drake Hotel, Chicago

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955, Lake Placid Club, Essex County, N.Y.

The Seventh Congress of the International Scientific Film Association will be held September 18–27 in the National Film Theatre and Royal Festival Hall, London S. E. 1. A Scientific Film Festival will be held, and in addition, meetings will be held by the Permanent Committees on Medical, Research, Technical and Industrial Films. There will be special sessions on the technique and application of films in medicine.

The Development of High-Speed Photography in Europe

By HUBERT SCHARDIN

The main features of European high-speed photographic instrumentation are described, including cameras using stationary film, those with intermittently or continuously moving film, and those incorporating the film drum. Methods of lighting high-speed photography with various spark arrangements are discussed.

Since it is hardly possible in a brief review to present a total picture of the development of high-speed photography in Europe, an attempt is made here to select data showing the general trend in the field during the past sixty years.

MECHANICAL METHODS

Cameras With Fixed Film Strip

It is a little-known fact that as early as 1892 the Prussian Armaments Testing Commission (Preussische Artillerie Prüfungskommission) constructed a camera in which the film was stationary, with a speed of 1000 frames/sec, the exposure time of each frame being 10^{-4} sec.

Figure 1 shows schematically the principle of this camera, which was certainly influenced by the work of Muybridge in California. For this early venture in high-speed photography, 12 cameras were set along the quarter-arc of a circle. Exposure was accomplished by a slit in a rotating disk with a diameter of 230 cm and a speed of 20 rps. The velocity of the slit was therefore the astonishing one for that day of 145 m/sec.

At that time the focal length of lenses was considerably greater than is used today, so that the distance between two cameras was 14.5 cm, resulting in a repe-

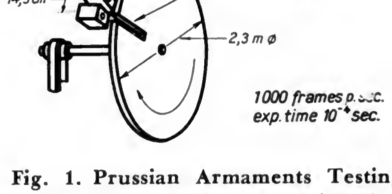


Fig. 1. Prussian Armaments Testing Commission high-speed camera (1892).

Presented on October 8, 1952, at the Society's Convention at Washington, D.C., by Hubert Schardin, Laboratoire de Recherches, St. Louis, France. *Residence:* Rosenstrasse 10, Weil am Rhein, Baden, Germany.
(This paper was received in revised form June 1, 1953.)

Fig. 2. Selection from a sequence taken with the Bull camera (3000 frames/sec) showing the entry of a ball into water.

tition rate of 1000 frames/sec. With modern short focal-length lenses, the same arrangement would produce a correspondingly higher framing rate. Lucien Bull (a colleague of Marey, the famous French pioneer in cinematography) built a similar camera in Paris in 1933. It was capable of taking 50 pictures on a single 13 × 18 cm plate at a speed of 3000 frames/sec. Figure 2, showing in successive stages the entry of a falling ball into water, is an example of the work of this camera.

About 1930, the firm of Askania in Berlin constructed a camera with 12 lenses; however, there were 13 slits in the disk, so that exposure was complete after a 30° rotation. The framing rate was 15,000 frames/sec.

The repetition rate increases as the lens diameters decrease. Therefore, with a 1-mm slit, operating at 100 m/sec, the exposure time per frame would be 10^{-5} sec, provided each exposure starts at the end of the preceding one. Under these conditions it should be possible to attain a rate of 100,000 frames/sec.

This has been achieved in the English Marley camera (Fig. 3), which has 59 lenses, and mirrors through which 59 images are reflected on a film strip.[1] The effective aperture is *f*/27; therefore only very bright objects may be photographed successfully. There are 16 slits in the rotating disk, requiring a rotation of 22.5° for exposure of all 59 frames.

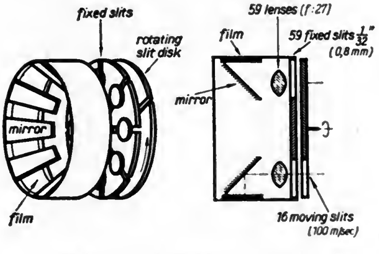


Fig. 3. The Marley camera (100,000 frames/sec) (1949).

Cameras With Rotating Light Beam

The next development is a simple one. The revolving mechanical slit disk is replaced by a rotating light beam, the speed of which can be, of course, increased considerably over that of the disk. The American Miller and Bowen cameras apply this principle, and it has also been applied in Europe.

First should be mentioned a design of the German firm of Rheinmetall (1944). This camera (Fig. 4) has an annular ring with 50 fixed lenses and a fixed film strip. The frames are exposed in succession by means of a rotating mirror. This method requires that the image on the film be stationary during exposure; therefore the intermediate image must be on the mirror. Because of the war, Rheinmetall was unable to complete the development of this camera, but the work has been carried on by the British Royal Naval Scientific Service.[2]

Another application of this principle is that of Bartels (Fig. 5). He substitutes

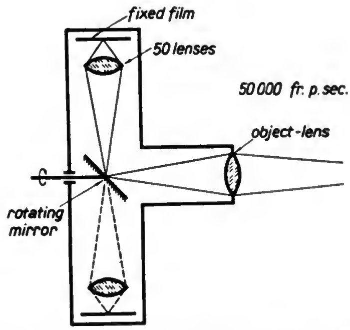


Fig. 4. The Rheinmetall camera (1944).

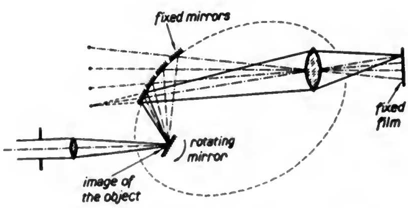


Fig. 5. The Bartels camera (1949).

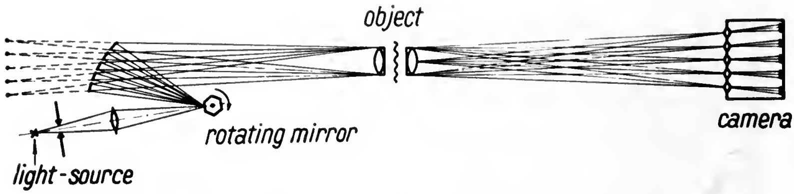


Fig. 6. Mechanical light control of the multiple-spark camera (Schardin, 1949).

fixed mirrors for the required number of lenses and uses only one object lens. Again an intermediate image is formed on the rotating mirror. Bartels' camera is very economical, since it can be set up with ease using the normal equipment of a research laboratory.

It is often very useful, particularly when schlieren illumination is required, to use a multi-lens system for mechanical light control. The resulting system behaves like a multiple-spark camera, but uses only one light source (Fig. 6). This may be regarded as the continuation of the multiple-spark principle into the region of lower framing rates.

Cameras With Intermittently Moving Film

All the cameras so far mentioned have the disadvantage of producing only a limited number of frames. The first remedy is the intermittent displacement of the film when exposure of a given segment has been completed; i.e. during exposure, and as long as the shutter is open, the film is at rest. It is interesting to note that Marey, in Paris in 1885, obtained 110 normal-sized frames/sec in his photographic gun. Even today it is impossible to achieve much more than double this rate, since the velocity of intermittently moved film cannot normally exceed 5 m/sec. Figure 7 shows an original Marey series of a dog in motion. The European Vinten, Debrie and Askania cameras produce about 250 frames/sec on 35mm film. It is perhaps surprising that intermittent cameras attaining the possible maximum for 16mm and 8mm film do not yet exist. It is interesting in this respect to mention the development by the Swedish Armament Department of an intermittent-motion camera with a speed of more than 1,000 frames/sec. The intermittent film motion is achieved by a film drive consisting in part of two splined rubber rollers.

Cameras With Continuously Moving Film

The first important camera using the principle of optical compensation and taking pictures on continuously moving film is certainly the "Zeitlupe" of Lehmann, built in 1916 by Ernemann and in 1928 by Zeiss Ikon. The use of the principle of compensation with a rotating polygonal mirror is schematically shown in Fig. 8.

It is probably unnecessary to describe this well-known camera in detail, since its use is now so widespread. It was first used for ballistics studies during World War I. At that time it had a speed of only 500 frames/sec. Rumpff proposed in 1916 to increase this rate by using three cameras in parallel connection, with an adequate phase shift of exposure times. Such a triple camera was subsequently developed, and others similar to it followed.

It is worth pointing out that the quality of the picture sequence produced by several cameras in this way is inferior to that produced by a single camera with a correspondingly higher framing rate. If the exposure time of one frame is greater

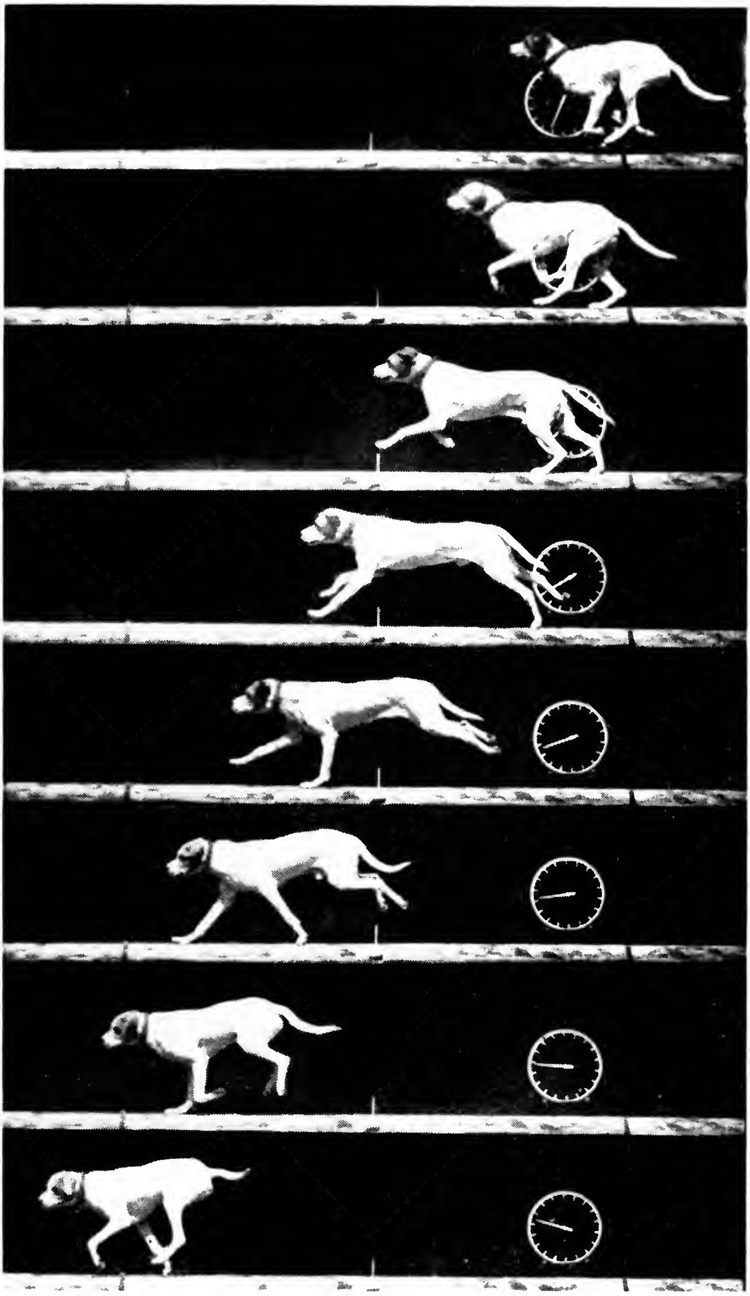


Fig. 7. Part of a sequence taken by Marey (120 frames/sec).

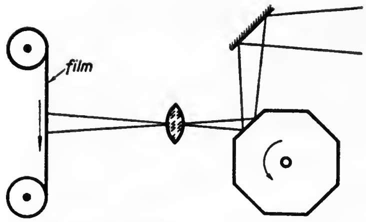


Fig. 8. The "Zeitlupe" camera (Lehmann, 250–500 frames/sec; Zeiss Ikon, 1500 frames/sec).

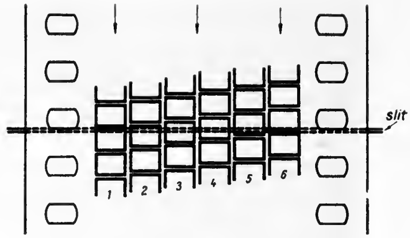


Fig. 9. Frame-division method of time resolution.

than the reciprocal of frame frequency, the blur caused by motion in the object is magnified and impairs clarity. In practice, three cameras in parallel connection have a time resolution only 37% higher than that of one of them operating alone.

Optical compensation can also be effected in other ways. In a number of cameras it is achieved with rotating prisms or lenses.

A camera employing an octahedral prism is the Rotax designed by Askania.[3] Though it produces only 600 frames/sec on normal film, it is worthy of mention since its images have fairly good resolution and its weight is only 13 lb. It can be hand-held during operation.

Optical compensation by means of rotating lenses has been applied since 1926 chiefly by Thun, whose cameras have been commercially produced by Askania and A.E.G. In France there are two similar cameras manufactured by Merlin-Gerin-Debuit of Grenoble. One is designed for 16mm film and has a speed of 3000 frames/sec; the other, for 8mm film achieves 6000 frames/sec.

An advantage of the A.E.G. camera is the fact that its lens disk is interchangeable with a slit disk. Moreover, each frame can be divided into a great number of small frames, up to 80, each of them only 1.8 × 3 mm in size. Thus an increase in exposure rate up to 80,000 frames/sec is achieved.

As early as 1936, Thun suggested the possibility of achieving practically continuous time resolution. As is seen in Fig. 9, a narrow slit traverses six individual frames, each of which is slightly displaced longitudinally (on the time axis). The slit therefore simultaneously exposes a different segment of each of the six frames. Were we to view these frames, not much time resolution would be evident, since the exposure times of the frames overlap considerably. However, by reconstituting into one picture all the segments exposed at the same instant, very good time resolution can be achieved.

Decreasing the size of the slit and increasing the number of frame divisions will bring about still better time resolution, but with considerable sacrifice in image quality. Therefore, in using this method it is important to fix optimal conditions for both these factors.

Drum Cameras

If a great number of frames is not required, one strip of film may be fixed on a rotating drum and the complexities of moving film avoided.

The first drum camera with optical compensation by mirrors in practical use is probably Rumpff's model of about 1928. The frame was 120 mm broad by 7 mm high, the speed 5000 frames/sec, and the length of film allowed for 50 frames.

The MGD firm of Grenoble, France, has manufactured a drum camera with rotating lenses, the arrangement of

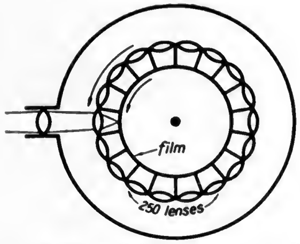


Fig. 10. The Merlin-Gerin-Debuit camera.

which is worth study (Fig. 10).[4] The film drum and the lens ring are one compact piece, rotating together. Optical compensation is provided by the difference between the tangential velocities of lenses and film. Three rings of lenses are set parallel in the camera, each ring taking 250 pictures. The speed is 33,000 frames/sec for each ring and would be 100,000 frames/sec for the three rings were it not for the fact that the exposure time for one frame is greater than the time difference between two parallel frames — a consideration which greatly reduces effective speed.

ELECTRICAL METHODS

The second group of photographic instrumentation tools is based on the electrical discharge of a condenser. To study a rapid phenomenon, it is not always necessary to use a high picture repetition rate; one sharp picture with sufficient detail sometimes gives excellent information.

Ernst Mach, about 1880, first made use of the electrical spark discharged from a condenser to photograph high-speed phenomena such as shock waves, explosions and moving projectiles. C. Cranz continued this work, achieving bright, brief sparks which made his shots, even by today's standards, models of fine still-picture technique (Figs. 11a and 11b).

The early simple form of electrical discharge in air is still used for photographic lighting, particularly when brief flashes are required. But much has been done in the last twenty years to increase the optical effectiveness of this method. Two factors have been important in this development: (1) the substitution of krypton or xenon for air; and (2) the prolongation of the discharge channel. Using these two factors, Harold E. Edgerton in America devised the first electrical flashlamps.

In our German laboratory, during the war, the guided-spark principle was used to prolong the discharge path. It becomes possible, for example, to increase the length of a 40,000-v spark from 15 mm (sphere) to 800 mm, and to increase brightness by the factor 10. An energy of 800 wattsec produced a guided spark in air which illuminated a surface 4 $\times$ 4 m sufficiently to take pictures with a Kerr-cell camera, the exposure time being 1 μsec. These guided-spark tubes, filled with xenon, are now produced under the name "Defatron" by the French Central Armaments Laboratory. Major Naslin has described this instrument in detail.[5]

Cameras Using Pulsed Spark Gaps

There are two methods of illuminating a motion-picture subject with sparks: (1) by flashing a series of sparks between the same electrodes; and (2) by the use of a multiple-spark gap. The first method encounters some difficulty such as image separation and the removal of ionization in the spark gap.

The simplest method of controlling the spark is a mechanical one. Lucien Bull in 1904 constructed the first spark camera, using this means (Fig. 12). With a rotating switch and an inductor he produced 2000 sparks/sec; 50 frames of normal size were taken on a rotating drum. The energy of each spark was, of course, not very great.

In 1905 Kranzfelder and Schwinning successively discharged 10 condensers through a single spark gap by means of a

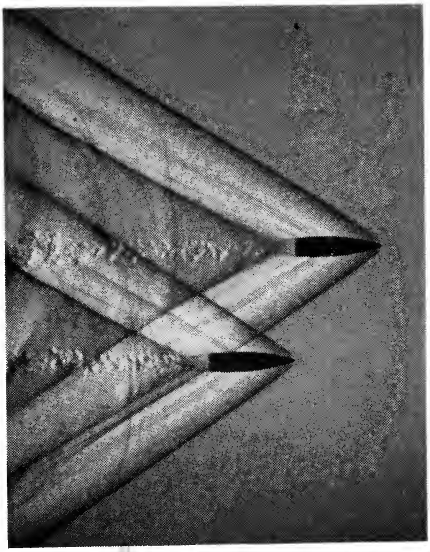


Fig. 11a. Schlieren exposure of two projectiles fired simultaneously.

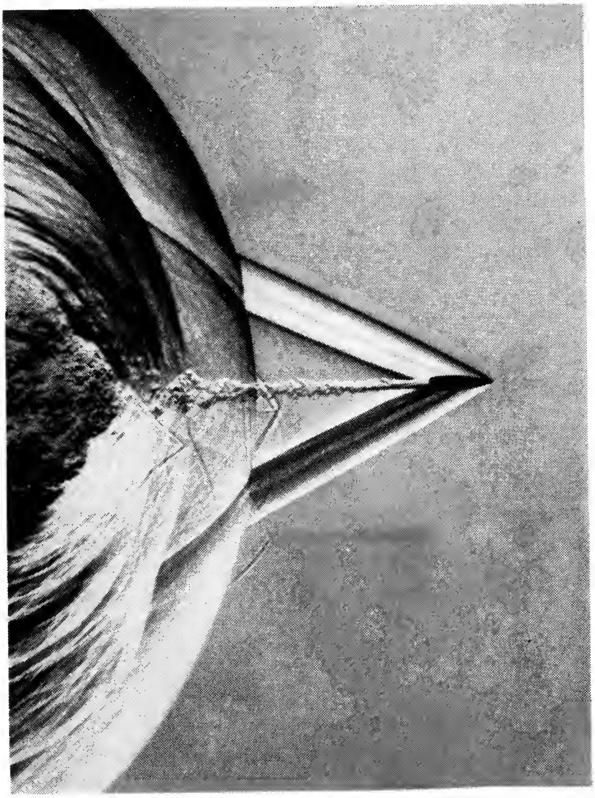


Fig. 11b. Projectile after exit of the nozzle shock wave.

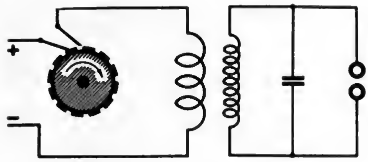


Fig. 12. The Lucien Bull spark camera (1904).

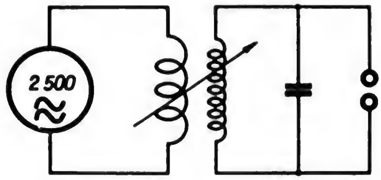


Fig. 13. The Cranz "Ballistics Cinematograph" (1909).

rotating switch. This principle is sometimes made use of today, as in the French LCA camera, which operates at a speed of up to 10,000 frames/sec.

Cranz's "Ballistics Cinematograph" of 1909 (Fig. 13) applied yet another principle. Here an oscillator feeds a pulse network. The condenser discharges at each half cycle at a frequency of 2,500 cycles/sec. The speed of the camera is 5000 or 10,000 frames/sec, using a rotating drum. Cranz used this camera often and successfully for the study of ballistics problems.

Another way of producing a series of sparks is through the alternating charge and discharge of a condenser (Fig. 14).

In 1912 Schatte used a resistance for spark control, attaining 50,000 sparks/-sec. In the same year Glatzel applied the principle of spark telegraphy with a result of 100,000 sparks/sec.

Yet a better method is the use of an inductance to control condenser-discharge (Toepler), since this involves no loss of energy. The operation of this arrangement has been calculated in recent years by Schering, Vollrath and Neubert.

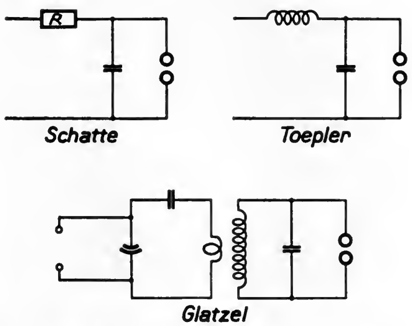


Fig. 14. Methods of spark control.

Repeated flashing of a single spark requires the separation of frames on the film, which makes high speed difficult to achieve (Fig. 15).

A film laid on the outside of a drum can achieve a velocity of 120 m/sec, and it is possible for a film with frames 10 mm high to attain 12,000 frames/sec. If the same film is laid on the inside of the drum, up to 25,000 frames/sec may be reached. A rotating mirror in the center of a fixed drum could produce a maximum rate of about 170,000 frames/-sec, but in this case a satisfactory flash of sufficient energy in the single spark gap is difficult to achieve, and the finite

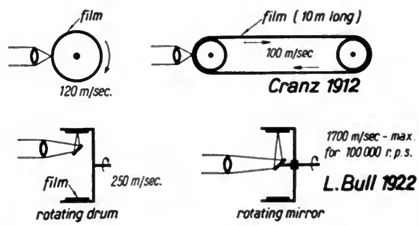


Fig. 15. Methods of frame separation on film.

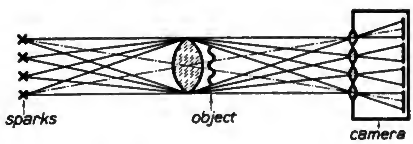


Fig. 16. The Cranz-Schardin multiple-spark camera (1928).

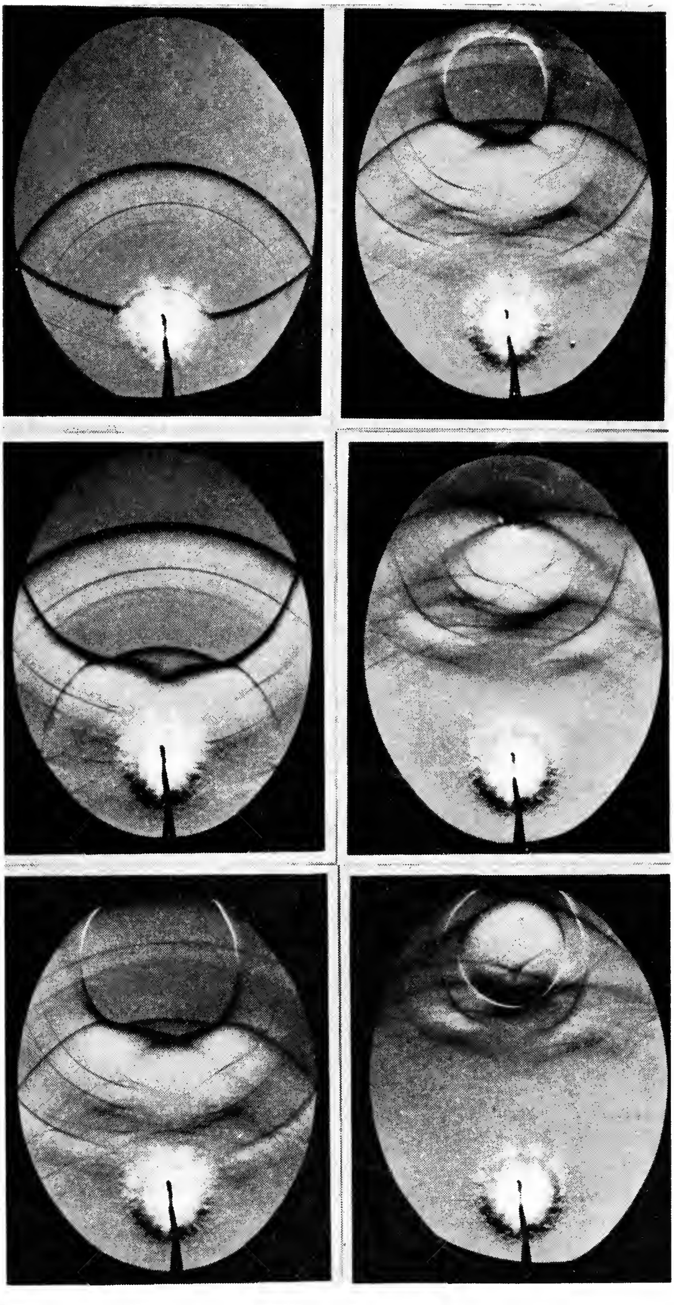


Fig. 17. Selection from a sequence taken with the Cranz-Schardin multiple-spark camera showing the reflection of a shock wave in an ellipsoid (30,000 frames/sec).

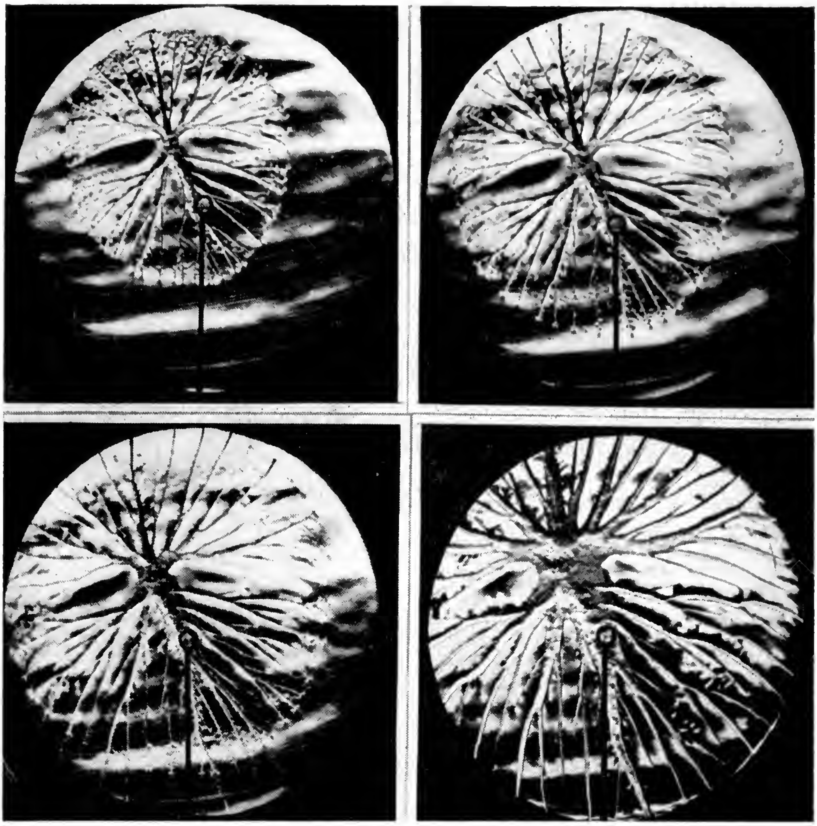


Fig. 18. Selection of sequence taken with Cranz-Schardin multiple-spark camera showing fracture of thin membrane used in a shock tube (80,000 frames/sec).

duration of the spark ($\sim 10^{-6}$ sec) will cause blurring.

The Multiple-Spark Camera

For high-speed photography therefore, the multiple-spark camera (Fig. 16) is preferred. Some of its advantages are as follows:

1. Exposure rates of 10^6 frames/sec and more present no difficulties.
2. The picture size does not depend on the exposure rate and can be large enough to show any data needed.
3. No moving parts are necessary, except perhaps for time measurement.

The shortcomings of the multiple-spark camera are, chiefly:

1. The limited number of frames which can be taken.
2. The presence of parallax.
3. The impossibility of photographing self-luminous phenomena.

In spite of these limitations, however, the multiple-spark camera is capable of such extraordinarily exact photography as to make it a most useful tool for photographic instrumentation. The time difference between two sparks can be measured with an accuracy of more than 10^{-7} sec, and the precision in location

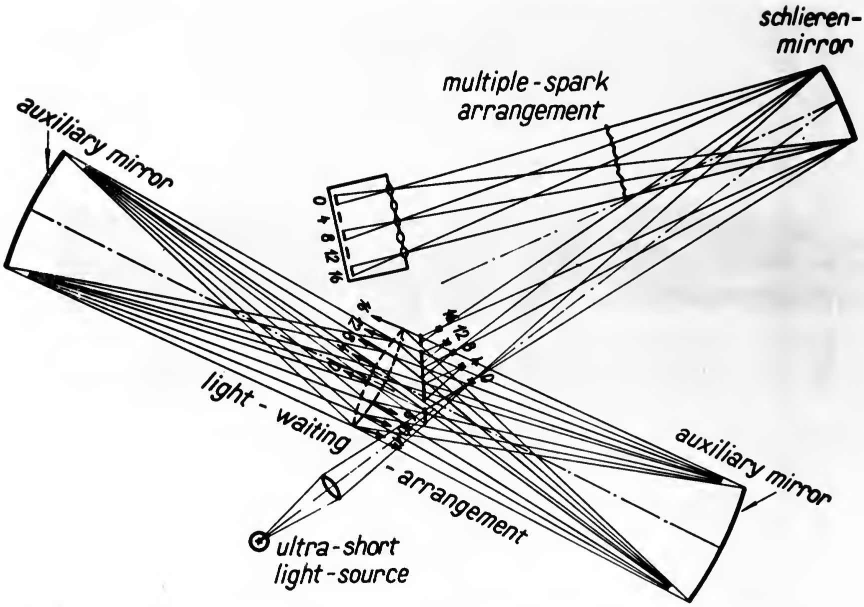


Fig. 19. Optical arrangement of ultra high-speed motion-picture camera based on Cranz-Schardin system using velocity of light (1949).

of a point in the object is about 0.1 mm. The error caused by parallax may be avoided by photographing a calibration grid on the same plate. Some idea of the applications of the multiple-spark camera is given in Figs. 17 and 18.

The usual electrical method of triggering successive sparks will produce a maximum of 10^7 frames/sec. If it is possible to flash only *one* spark of sufficient brightness, and shorter than 10^{-7} sec, the optical arrangement shown in Fig. 19 will produce a higher exposure rate.

Before entering the camera, the light of the spark is reflected several times by two auxiliary mirrors. After each two reflections comes the next light beam, the time delay being dependent on the velocity of light and the focal length of the auxiliary mirrors. An exposure rate of about 10^9 frames/sec appears to be possible.

Kerr-Cell Cinematography

The separation of pictures in the multiple-spark camera is based on the fact that an image of the multiple sparks is formed in the corresponding lenses.

This principle does not function (a) in daylight, (b) if the object is self-luminous, or (c) if the object is to be studied in reflected light.

If any of these conditions must be met, the Muybridge equipment, as described above, is used, but with Kerr-cell shutters. In our laboratory, during the war, we used eight Kerr cells, of which two were used jointly to take stereoscopic pictures. The Kerr cells had a 37-mm aperture and were controlled by 40,000 v. When objects were to be photographed in daylight or by reflected light a guided spark was flashed to supply the light necessary for an ex-

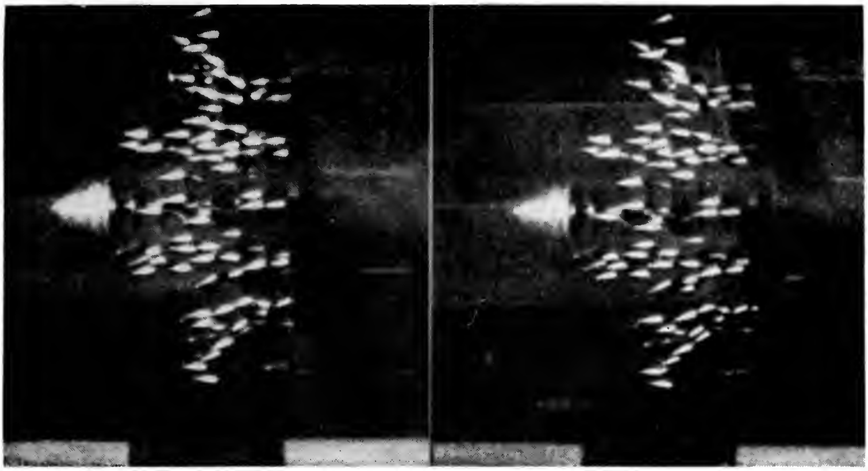


Fig. 20. Stereoscopic Kerr-cell exposure of a bursting shell filled with small projectiles.

posure time of about 1 μsec. In each case two Kerr cells formed an electrical unit; the time difference between the opening of two successive shutters could be regulated from 1 μsec on up. Figure 20 is an example of the results achieved by this process.

Image-Converter Photography

Another possible constituent of the electrooptical shutter is the image converter, known in the field of television. In collaboration with the A.E.G. research laboratory, E. Fünfer of the Laboratoire de Recherches, developed (1940) a convenient converter tube arrangement. Photographs thus produced were somewhat inferior to those made using the Kerr-cell technique, but further research, such as that now being made by Courtney-Pratt in England, may bring about improvement.

In a review such as this it is impossible to mention every aspect of European high-speed photographic development; among other matters, mention of methods of triggering or of the use of X-ray flash sources has necessarily been omitted. It is hoped that this brief summary will have given American engineers at least a broad general idea of European high-speed camera achievements.

References

1. G. A. Jones and E. D. Eyles, "Recent British equipment and technique for high-speed cinematography," *Jour. SMPTE, 53:* 502–514, Nov. 1949.
2. W. Deryck Chesterman, "History and present position of high-speed photography in Great Britain," *Jour. SMPTE, 60:* 240–246, Mar. 1953.
3. Addendum to Progress Committee Report: Developments in Germany, *Jour. SMPTE, 60:* 680–687, June 1953.
4. Paul M. Gunzbourg, "High-speed motion picture cameras from France," *Jour. SMPTE, 58:* 256–265, Mar. 1952.
5. P. Fayolle and P. Naslin, "Simple electronic devices for high-speed photography and cinematography," *Jour. SMPTE, 60:* 603–626, May 1953.

A Microsecond Still Camera

By HAROLD E. EDGERTON and KENNETH J. GERMESHAUSEN

A shutter with an effective open time of about 1 μsec is described which was specially designed to photograph high explosives during detonation. Precision adjustment of the exposure instant by a time-delay circuit triggered by the explosion light is used for synchronization. Optical systems of focal lengths of 6 in. to 6 ft have been employed. Examples are given of pentolite and TNT explosions.

Experiments with high explosives using a previously described magnetooptic shutter* indicated that a shorter exposure time would be advantageous in studying high-velocity shock waves and flame fronts. Accordingly the equipment herein described was designed with every effort to obtain a simple, rugged field instrument with a 1-μsec shutter open time.

The Magnetooptic Shutter

The complete camera assembly as used for field work is shown in Fig. 1. The microsecond shutter is located in the square-shaped aluminum casting. On the back of this casting is a mounting position to accept a 4 × 5 in. Eastman view camera, although almost any camera can be used with slight modification of the base. Provision is made on the back side of the magnetooptic shutter to fit the lens ring of a Wollensak shutter containing a 163-mm focal-length lens. The "X" synchronizing contacts on the Wollensak shutter enable the operator to fire his explosive charge without a long open time which might fog the film due to light leakage through the closed polarizers. An image of a subject illuminated by direct sunlight will be dimly exposed in 10 sec with fast film even if the polarizers are accurately crossed.

The magnetooptic shutter described in this paper was the result of a redesign of the previously designed 4-μsec model in the following ways:

1. The aperture was reduced from 1 in. in diameter to 1 cm.

2. A single pair of Polaroids instead of two crossed pairs was used.

Presented on May 1, 1953, at the Society's Convention at Los Angeles by Harold E. Edgerton (who read the paper) and Kenneth J. Germeshausen, Edgerton, Germeshausen & Grier, Inc., 160 Brookline Ave., Boston, Mass.
(This paper was received March 27, 1953.)

* Harold E. Edgerton and Charles W. Wyckoff, "A rapid action shutter with no moving parts," *Jour. SMPTE, 56:* 398–406, Apr. 1951.

3. The capacity was decreased from 4 to 0.3 μf.

4. A spark gap and capacitor assembly was designed to eliminate as much circuit inductance as possible.

The main capacitor circuit consists of ten 0.03-μf capacitors in parallel, arranged to have a low interconnecting inductance. Figure 2 shows the assembly in the casting that encloses the capacitors and the magnetooptic shutter together with the gaps and associated pulse transformers.

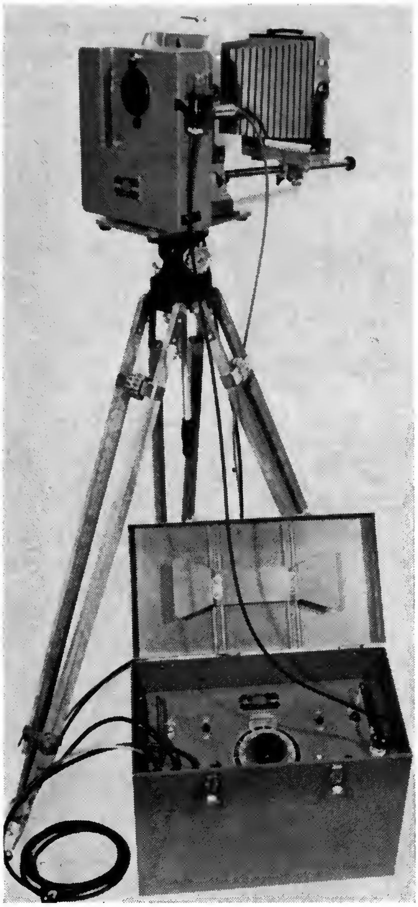


Fig. 1. One microsecond shutter in square case in front of a 4 × 5 in. view camera. Note photoelectric cell on side of shutter for triggering from the light pulses from explosions. The box at the bottom includes power supplies and control circuits.

Figure 3 shows a cross section of the magnetooptic shutter as well as details of the electrical circuit that pulses the 5-turn coil around the extra-dense flint-glass magnetooptic element. The glass is constructed of Bausch & Lomb Type EDF-4 annealed glass in the form of a cylinder 1 cm in diameter and 2 cm long. The two-gap circuit is used to excite the shutter coil for a half-cycle as has been described in the reference given above. These two gaps are shown in the diagram, Fig. 3, together with the pulse transformers that trigger them.

The "A" pulse coil initiates the discharge of the 0.3-μf capacitor into the coil around the glass element. The "B" pulse coil triggers the quench airgap which short-circuits the main capacitor into a damping resistor after a half-cycle of operation. In this manner, the energy in the circuit is removed so that the capacitance, C, and inductance, L, will not oscillate.

The light-time transmission of the shutter under normal operating conditions is shown in Fig. 4, as sketched from oscillographic observations. The 100% light transmission refers to the transmission with the polarizers (Type HN23) in a parallel position which corresponds to a density of about 1. The transient open-transmission density is close to that of the uncrossed condition since the rotation is about 90°.

Electrical cables connect the camera and shutter portion to the power supply and control unit, which are in the box shown on the floor in Fig. 1. Details of the delay and trigger circuits in the control unit are given in Fig. 5. The trigger portion of the circuit is usually a photoelectric tube, marked 929 on Fig. 5, although a "make" circuit or a positive voltage pulse is equally effective. The

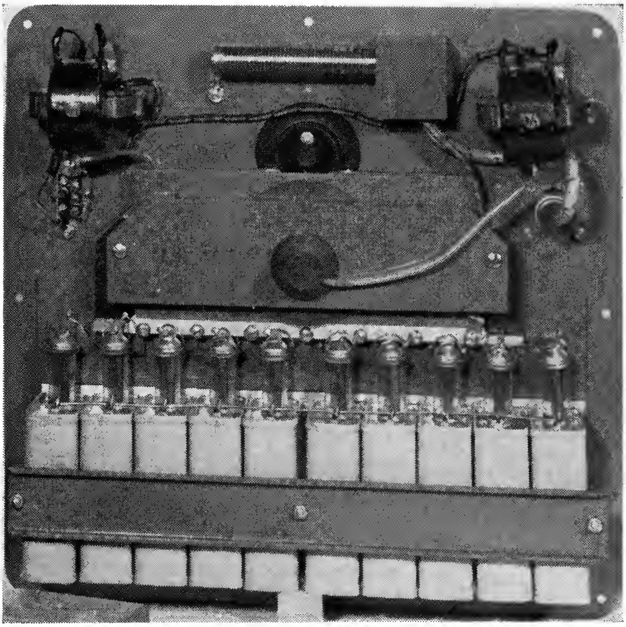


Fig. 2. Inside view of the magnetooptic shutter showing capacitors, spark gaps, trigger transformers, etc.

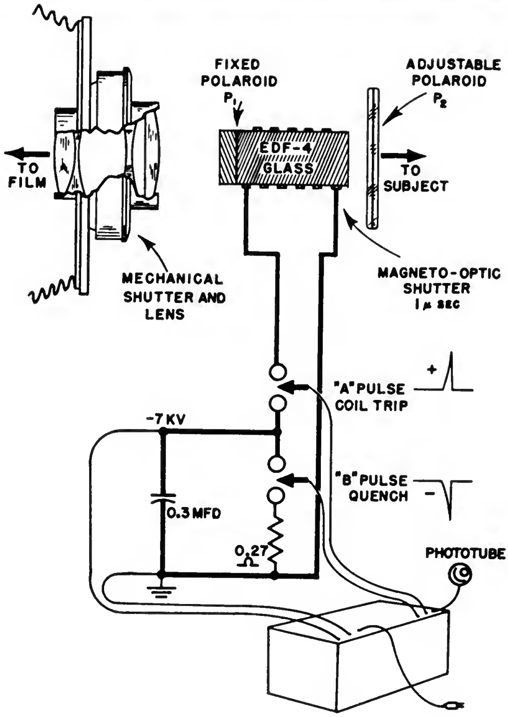


Fig. 3. Cross-sectional view of magnetooptic shutter and driving circuit.

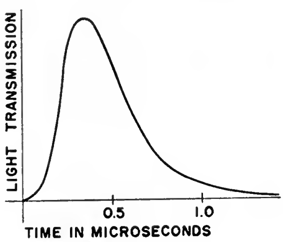


Fig. 4. Transmission of the magnetooptic shutter as a function of time.

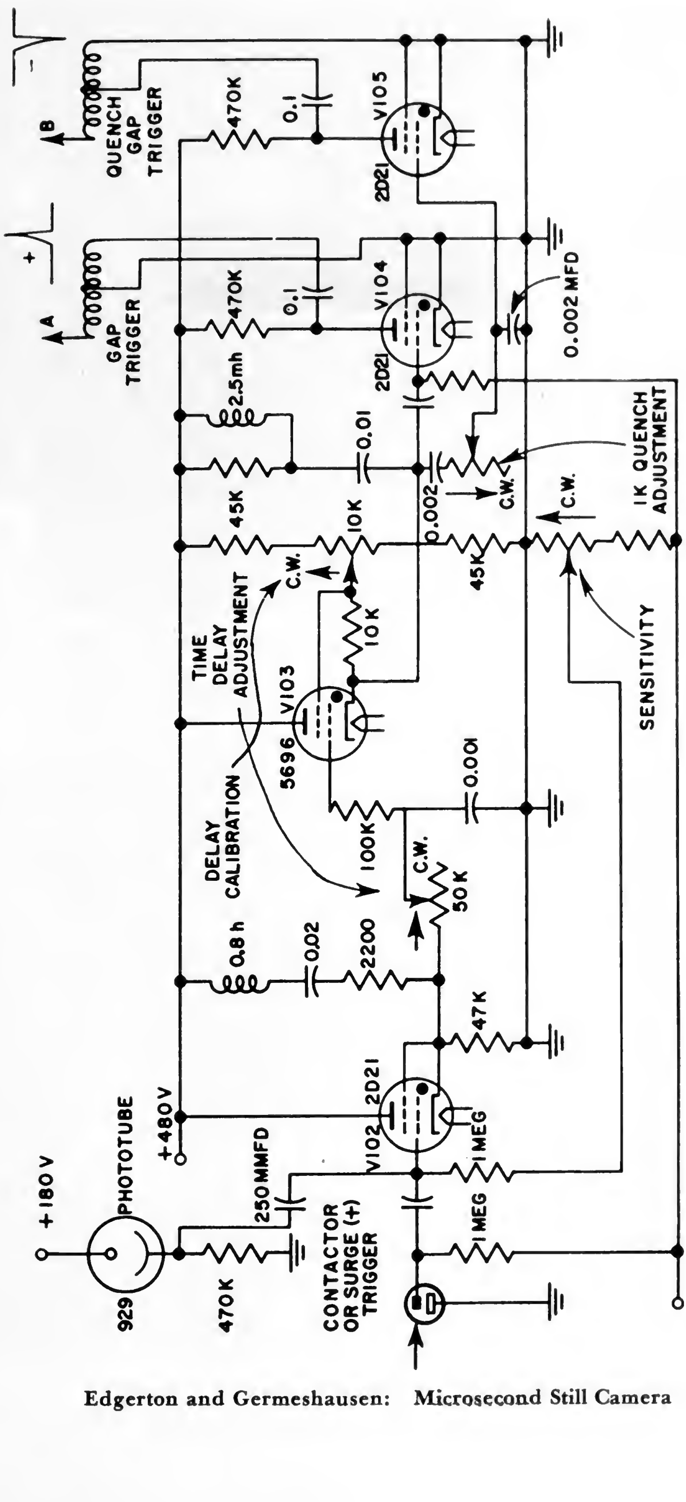


Fig. 5. Control and time-delay circuits for magnetooptic shutter.

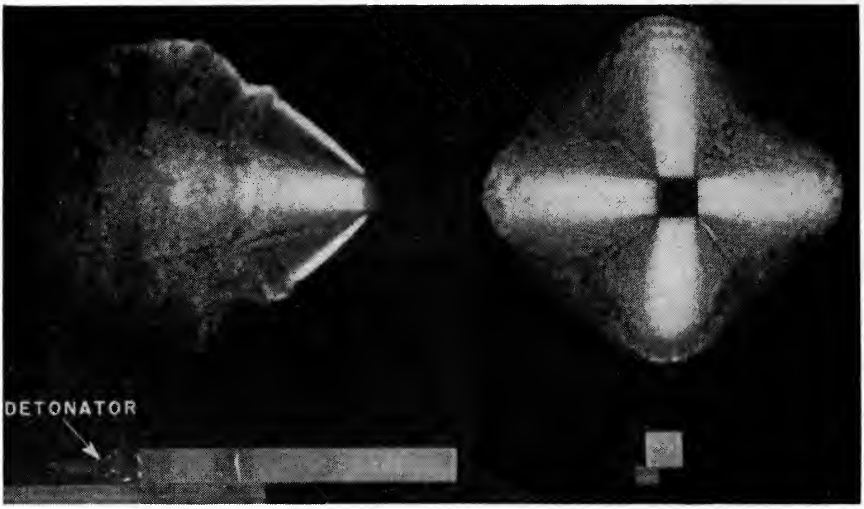


Fig. 6. Composite photos. Below: a square stick of Pentolite $\frac{3}{4}$ in. on a side and 6 in. long. Note fractured portion repaired with scotch tape. Above left: a 1-μsec. exposure with an EG&G Type 2208-0 Rapatronic camera timed 15 μsec following initiation. Note ripple in shock flame front corresponding to fracture. Also note that luminosity does not start at the detonation front on the stick. Above right: end view of a similar explosion. (Photos taken at the Ballistic Research Laboratory, Aberdeen Proving Ground.)

flash of light from a subject illuminates the photocell creating a voltage pulse which trips the thyratron (V102) and the delay RC network. A dial on the unit controls the resistance (50 K variable) of the RC coupling portion of the circuit. The pick-off thyratron (V103) triggers after the time delay as determined by the pick-off voltage on the adjustable resistor (10K). The coil "A" exciting thyratron, V104, triggers instantaneously with V103 followed in about $\frac{3}{4}$ μsec by V105 which triggers the quench gap and coil "B."

Examples showing $\frac{3}{4}$-in. square sticks of pentolite as they explode are shown in Fig. 6. These photographs were made with the camera of Fig. 1 with the time delay set at 15 μsec. The explosions were in a heavy-walled concrete chamber at the Terminal Ballistic Laboratory at Aberdeen, Md., where a thick glass window of the shatter-proof type permitted the camera to be placed close to the explosions without danger.

An interesting and often useful effect results when the quenching gap is prevented from firing. One method of accomplishing this is to remove the thyratron V105 from its socket. If the quench gap does not operate, then the current through the shutter coil will oscillate at the natural frequency of the circuit consisting of the capacitance, C, and coil inductance, L, as given by

$$f = 1/2\pi\sqrt{LC}\ \text{cycles/sec}$$

The shutter does not depend upon the polarity of the current, therefore the shutter will open twice per cycle. The frequency is about one million times per second. Figure 7 shows the same subject as Fig. 6 when photographed with an undamped shutter. Note the interesting

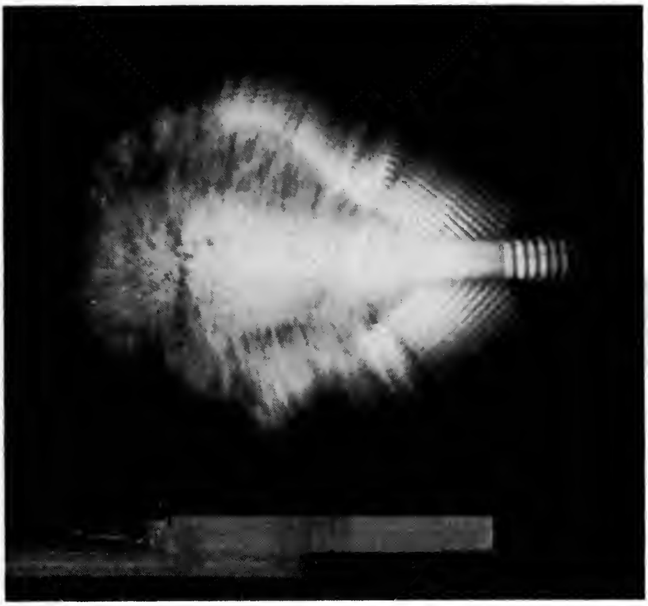


Fig. 7. Below: two 3-in. sections of $\frac{3}{4}$-in. square Pentolite sticks taped together with scotch tape. Above: same subject photographed by EG&G Type 2208-0 Rapatronic with shutter oscillating 1 mc. (Tube V105 has been removed so that the quench gap does not fire.) Note high velocity of products from the end of the explosion.

end effects when the explosion reaches the end of the explosive.

Teletronic Assembly

The shutter previously described has been used also with two telescope types of mirror optical systems of long focal length. In this way large explosions can be studied photographically from a safe distance.

One of the telescopes was a Wollensak 40-in. Mirrortel. The primary image was formed in the magnetooptic glass element and subsequently enlarged twice on a 35mm Exakta Camera. The reflex features of this camera were used for initial alignment and focus. A "before" photograph was taken immediately prior to detonation to show size and any unusual features.

A photomultiplier tube was used to trigger the magnetooptic shutter for the distance photographs (approximately 750 ft). A tube with small holes at both ends was used to exclude most of the daylight that would saturate the tube.

The other telescope was a Newtonian system of about 6-ft focal length. The primary image was again brought out at the front of the telescope by means of a small right-angle mirror into the magnetooptic shutter. As before, the image was then enlarged twice on a 35mm Exakta Camera.

Photographs of one of the telescope cameras and examples taken with it at the Aberdeen Proving Ground are given in accompanying figures.

Often a series of accurately timed photographs is desired when an explosive

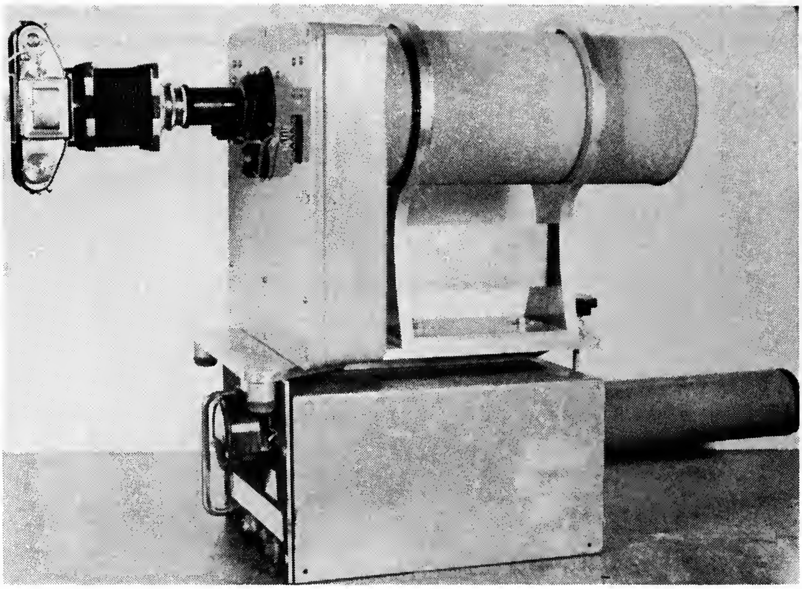


Fig. 8. Wollensak Mirrortel (40-in.) mounted on a 1-μsec shutter with an Exakta Camera. Below is photomultiplier trigger.

event is studied. To accomplish this, a series of several magnetooptic cameras can be used, each with a different time delay. A sequence of pictures like these can be compared to a motion-picture record, except that the rate may be irregular as set on the time-delay dials and the pictures can be taken with different lenses. Furthermore, very few motion-picture cameras can operate at cycling rates or individual exposure times corresponding to those obtainable from the magnetooptic shutter. The focal lengths of the lenses can be changed to cover the subject properly at the required instants of time. Stereoscopic photographs of explosions can also be taken by using two cameras that have the same delay but with different positions of the cameras in space.

The 1-μsec magnetooptic shutter with photoelectric triggering and time-delay circuits provides a convenient new field research tool for the explosive engineer and scientist. Especially with long focal-length optics, excellent resolution of explosions in space can be obtained at a safe distance and without the necessity of elaborate protection. Shutter synchronization by means of light from the explosion is most convenient since no electrical or mechanical connection to the explosion is required.

Discussion

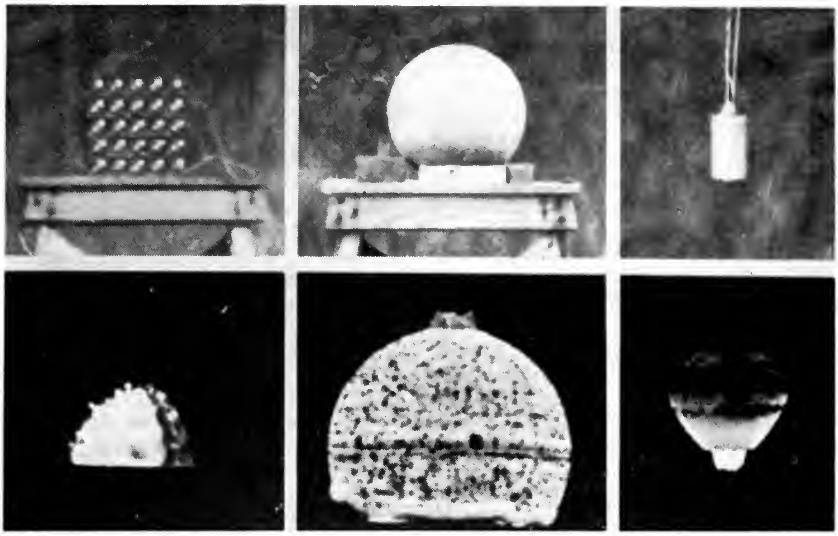
Anon: Has any attempt been made to synchronize the optical shutter technique with moving film?

Dr. Edgerton: No.

Anon: It sounds as though it would be a very potent idea.

Dr. Edgerton: Compared to the Kerr cell our exposure is very long. As we saw the other day, it is possible to get very sharp definition with the Kerr cell, while the duration of the magnetooptic shutter is quite a bit longer.

Anon: One of the major advantages that a d-c driven motion-picture camera has to



25 blocks of TNT (above) and (below) detonation.

65-lb pentolite sphere (above) and (below) 30 μsec after detonation.

Cylindrical charge (above) and (below) after detonation.

Fig. 9. Teletronic photographs taken with Wollensak 40-in. Mirrortel and 1-μsec shutter shown in Fig. 8, at a distance of about 750 ft (Ballistic Research Laboratory, Aberdeen Proving Ground).

offer all the way along is that it permits higher and higher camera speeds resulting in shorter and shorter exposures.

Dr. Edgerton: Well, we get shorter exposures another way. The Rapatronic camera is simple. The 110-v a-c power supply weighs only 35 lb and the camera weighs less. When a picture interval in milliseconds is required with a total of 50 pictures, just get 50 of these, line them up, set the lights, and all 50 of them will go. If you want 100 of them, get 100. What difference does it make?

With this approach to the problem, you get as many pictures as you need. Every effort has been made to get the simple, reliable field tool; not a complicated thing with jets, turbines and other fancy affairs. This 1-μsec shutter has been designed in an effort to get an everyday working tool, just like your automobile or jacknife. For explosion engineers it seems to me it's a natural. Up to now there was no tool except slit-type cameras to measure the velocity, so they have been living on a one-dimensional world. All the data are merely recorded on a slit to get velocity of the detonation. The Rapatronic camera records a two-dimensional world, with an excellent, clear image.

Anon: Did you take the before-and-after pictures through the same optics, and, if so, did this require moving the optical shutter out of the path?

Dr. Edgerton: Yes, with the earlier model used at that time. It's very important to get a complete still picture of the subject for reference. We used to do it by shining stroboscopic light on the subject and then triggering the shutter. On the current model one simply rotates the lever and the optical shutter is open, permitting focus on a ground glass.

In fact, you use the mechanical shutter just like you would in normal photography. The only difficulty you have is that in the "open" position two polarizers are parallel and produce a density of approximately one, and experience dictates the excess exposure required. Then you have to remember, of course, to close the optical shutter. That is like pulling your dark slide; it is very important.

Lawrence F. Brunswick (*Colorvision Inc.*): Is it possible that the apparent lack of luminance at the point of explosion in these photographs is actually a result of considerable over-exposure and consequent reversal?

Dr. Edgerton: Mr. Sultanoff, would you answer that?

Morton Sultanoff (*Aberdeen Proving Ground*): We have experienced this condition, and I would say quite positively that it is not the result of reversal from over-exposure. Much more work on this matter was published recently in open literature by the Bureau of Mines. I think this was in their October-December "Physics and Chemistry of Explosive Phenomena" progress report. Their explanation is based on theory which predicts that a rarefaction wave moves in from the surface and causes the pressure in the detonation front near the surface to be reduced in bare charges. This makes the detonation velocity lower, and consequently results in a front that curves back at the surface. The appearance of the shock not joining the detonation front at the surface is explained in the Bureau of Mines report as the result of that curvature. If you are interested you might contact them — the group under Dr. Bernard Lewis — for more information.

Wallace Allan (*Naval Ordnance Test Station, Inyokern, Calif.*): Does the field of view of the shutter have any advantage over the Kerr cell? The Kerr cell is limited to a rather small field of view.

Dr. Edgerton: No, these pictures are taken with a standard 4 × 5 camera with fixed lens. The image size on the film is about an inch.

Mr. Allan: That is a fairly small angle, if you desire as much as 60–70°.

Dr. Edgerton: The shutter will accept 70°. A 6⅝-in. lens and 4 × 5 plate can record a maximum of 50°. It is the object that must then be big enough.

Anon: Could your system find application, perhaps, in photographing the burning of kerosene?

Dr. Edgerton: There are two functions of this shutter: One is to keep the light out for exposure. You might want to use one of these shutters to eliminate light. That is like the example of the firecracker that I showed you. The other is when you photograph the light from the explosion. Now I doubt whether burning kerosene has a high enough light level to record during this relatively short exposure time. This shutter is a new thing, and we are still looking for new uses for it. There aren't too many people who shoot off explosions.

Benefits to Vision Through Stereoscopic Films

By REUEL A. SHERMAN

This paper emphasizes the need for good engineering in the production of stereo films to insure conformity with normal patterns of psycho-physiological functions of binocular vision. It describes the impact of stereoscopic motion pictures on the ophthalmic world and outlines some of the therapeutic benefits from viewing stereoscopic motion pictures. An orderly program is needed to inform the public of the potent stimulation to good binocular vision which results from viewing properly produced and projected stereoscopic motion pictures.

LET US LOOK IN at a Main Street theater in our average American city. The last row of seats is 75 ft and the front row is 22 ft from the screen. John and Jane Doe have come to see the new stereoscopic feature. They have taken the average seat 50 ft from the screen.

John is a skilled mechanic, an average American citizen, 35 years of age, in good health. He has good vision, eyes that are skillful. They function smoothly, effortlessly and instantly. The glasses he wears help to give him this efficiency.

Jane is the same age, and a good housewife. She wears no glasses. She has been told by her doctor that she should wear a prescription but she doesn't. Her trouble is not in her ability to see clearly because her acuity in each eye is excellent, but for other reasons she is visually uncomfortable.

The feature starts. John and Jane put on their polarizing spectacles and settle back comfortably for an evening of thrilling entertainment. Before the show is over, John is having trouble. His ordinarily skillful, efficient, binocular vision is causing him obvious discomfort. On the other hand, Jane who usually experiences difficulty is enjoying the performance with greater freedom from symptoms of visual disturbance than she ordinarily has in her daily occupations.

The cause of this apparent incongruity is in the vertical displacement of the two images. By not keeping the two images in frame, the projectionist has put an unnecessary burden on 98% of the patrons in the theater. By so doing he

Presented on April 27, 1953, at the Society's Convention at Los Angeles by Reuel A. Sherman, Bausch & Lomb Optical Co., Rochester 2, N.Y.; previously published in part in the *Bausch & Lomb Magazine*, vol. 29, No. 1.
(This paper was received April 19, 1953.)

has made it easier for the remaining 2% including Jane. The screen image from the right-eye projector is not framed vertically with the screen image from the left-eye projector. Jane has a right hyperphoria. The visual axis of her right eye tends to be above that of her left eye. The improperly projected picture automatically compensates for her visual impediment.

On the other hand, the 2% of the patrons in the theater who have a *left hyperphoria* are penalized even more than John who represents the 96% with correct vertical phorias.

John's eyes were not harmed even though he experienced discomfort from the abnormal visual gymnastics which they performed in maintaining fusion of the improperly aligned frames. No physiological damage could have resulted. Nevertheless the discomfort was unwarranted.

Vertical alignment of the frames and synchronization of the two projected pictures must be exact. Had the right-eye and left-eye frames been precisely and correctly aligned, Jane probably would have had considerable discomfort while 96% of the customers, including John whose eyes were in normal balance vertically, would have been comfortable and happy. This would have re-emphasized to Jane her need for professional, ophthalmic services for her own general well-being both in and out of the theater. The stereoscopic pictures could have been the stimulus needed for her to put her visual house in order.

The illumination from the two projectors should be matched as equally as possible. If relative illumination between right- and left-eye images varies more than 12%, some individuals may find that interference with their binocular vision results.

A small number, approximately 2% of the population, have better and more efficient binocular vision when the right-eye visual image is more luminous than the left-eye visual image. Another 2% have more efficient binocular vision when the left-eye image is more luminous than the right-eye image.

Slight differences between the visibility of right- and left-eye stereoscopic pictures do not seem to bother the average individual. But when the 2% whose eyes perform better with less luminosity in the right eye get more of it by unequally balanced illumination in the projectors, the tendency is to aggravate a latent condition which interferes with binocular efficiency.[1,2,3]

The projection lenses should be matched. It is recommended that variances between the right- and left-eye lenses do not exceed plus or minus 0.5% in focal length. For another example, let us consider a second couple sitting in the Main Street theater at a distance of 50 ft from the screen. He has excellent visual acuity in each eye, good binocular functional ability, while she has difficulty with any visual task that requires or induces sustained visual concentration such as an automobile trip, watching television, attending the conventional movies, or sitting through a lecture or sermon.

Again, viewing the stereoscopic motion picture brings comfort and satisfaction to her, while to him it brings a visual disturbance. Again the projectionist in this particular theater has something wrong with his equipment. The projection lenses are not matched. The right eye projected image is larger than the left eye projected image. In her case there was a disparity in the size of her retinal images which has not been corrected through ophthalmic care. The improperly matched projection lenses favored her condition so that she experienced a false sense of comfort while he who was not accustomed to disparity in size of images was irritated. This failure to match the lenses had benefited 1% of the audience and penalized 99%.

It seems that we have picked on the

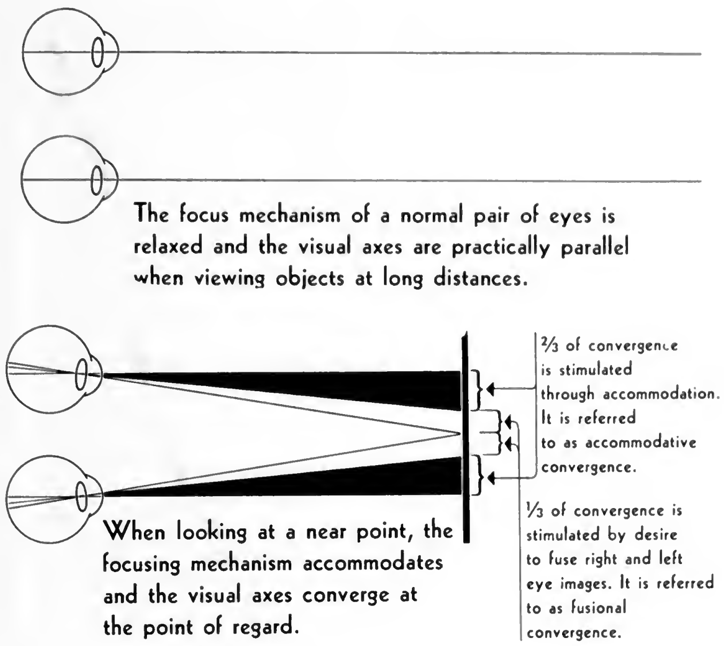


Figure 1

projectionist in the Main Street theater as having committed mechanical errors. Surely we can conceive of no combination of all such circumstances happening in any one theater during the exhibition of any one feature. Nevertheless, one of them can easily happen if conditions are not checked carefully.

The penalizing of producers, theater owners and the public through lack of attention to these details is unfortunate. A small percentage of patrons with visual difficulties will be favored by such errors, while the majority with normal binocular vision will be disturbed. These conditions should be reversed so that those with normal binocular vision will be stimulated to even greater enjoyment of the feature, while those who should do something about their visual performance will receive the incentive to act in their own behalf.

Of the customers who view stereoscopic motion pictures 85 to 88% can enjoy them without feeling visual tension or discomfort, providing consideration is given to those projection problems which we have covered, and providing the films are properly produced. The relationship between two visual functions, accommodation (focus) and convergence, probably is one of the important factors to consider in the production process. An understanding of the inter-relationship between these two visual functions may help in outlining certain rules. The accommodative-convergence relationship in a pair of human eyes will be considered only as it relates to the production of stereoscopic pictures and as the viewing of the pictures influences these functions.

Figure 1 illustrates the relationship between the focusing of a pair of eyes and their converging toward and on the point of regard. As the normal pair of eyes changes fixation from a "long shot" to a "close-up," or from a far point to a near point, two demands must be met to obtain single, clear binocular vision:

1. The focusing action of the eyes must adjust so that a sharp image will appear on each retina.

2. The 12 extra-ocular muscles must coordinate to turn each eye so that it will look precisely at the object of regard.

To a large extent binocular seeing is a learned function.[19] Some of us learn to see with skill and efficiency; others do it clumsily, haltingly, and inaccurately. In the average individual these complex adjustments are made instantly and with effortless facility. Through the conditioning of reflexes or other psychophysiological functions, a stimulation to convergence induces accommodation and inversely a stimulation to accommodation induces convergence.

Two-thirds of the amount of convergence required for fixation ordinarily is induced by the effort to accommodate. In Fig. 1 the shaded area represents this amount, which usually is referred to as accommodative convergence. The remaining third usually is referred to as fusional convergence. Fusional convergence is a reflex action induced by the mental desire for a single image. It is achieved by the eyes turning so that the image of regard is on corresponding points of each retina. Most of us with binocular vision demonstrate varying degrees of this accommodative convergence relationship with the great majority grouped around the limits indicated by this figure.[21]

We have emphasized the importance of accommodation in stimulating convergence but conversely the effort to converge also stimulates accommodation. This accommodation convergence which works both ways has been established through habit and learning. Those of us with effortless, skillful binocular coordination will converge when a stimulus is applied and still maintain our accommodation at the point where it is required for sharp focus. Others have little latitude between their accommodation and convergence. They have what might be referred to as a "tight hook-up" between the two functions. They cannot relax one function easily while stimulation of the other is maintained.

Such individuals usually have the ingredients for very efficient seeing, but interfering reflexes in their accommodative-convergence habits cause functional opposition often associated with discomfort. Their convergence may be overstimulated by their accommodation. In other cases there is little or no interfunctional stimulation. Their accommodative effort does not induce convergence, nor does their convergence effort induce accommodation.

These abnormal situations are problems for the skilled ophthalmic practitioner. The accommodative-convergence relationship, however, has an engineering connotation in the production and projection of stereoscopic motion pictures.

More often than not, those who lack flexibility between the functions of accommodation and convergence have excellent acuity with each eye. Judging their visual abilities solely by the sharpness of their sight, such individuals are lulled into a false sense of security — into a feeling that such excellent acuity precludes any need for professional services. Such subjects probably will be identified as needing professional attention by discomfort resulting from their viewing of stereoscopic motion pictures.

Figure 2 illustrates the impact of viewing stereoscopic motion pictures on the accommodative-convergence functions. It also illustrates the importance of considering these factors in producing films. In binocular performance, our accommodation gives us our sharp clear images by which we identify the object of regard; whereas convergence enables the two eyes to fixate or center upon the object of regard, so that single vision is maintained. In stereoscopic motion pictures our ac-

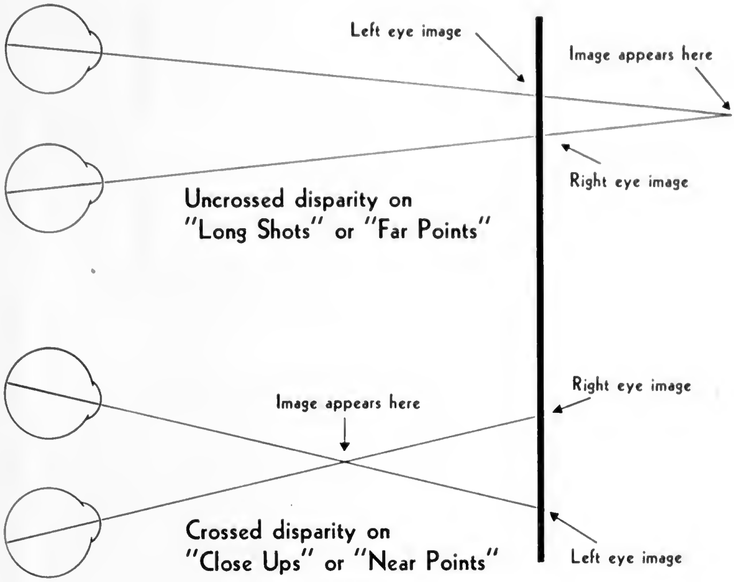


Figure 2

commodation gives us our sharp clear images. Our convergence localizes the objects in space either in front of or behind the screen (stereo windows). Efficient and effortless viewing demands new and independent responses from the two functions. Accommodation (or focus) must be maintained constantly on the surface of the screen if the individual is to see a sharp image. Convergence must act with independent flexibility so that each eye will point to its own image without the aid of accommodation, or conversely without interfering with the maintenance of it on the surface of the screen (stereo window).

In other words, those people who converge skillfully, independently of their focus, get a stimulating calisthenic experience from viewing properly made stereoscopic motion pictures. Such practice teaches them to converge when the stimulus to convergence is presented and to accommodate when the stimulus to accommodation is presented. Viewing stereoscopic pictures provides an excellent exercise in developing flexibility between the two functions and precision in each one. Fortunately such individuals are by far in the majority. On the other hand, those who have a "tight hook-up" between their accommodation and convergence should profit greatly from ophthalmic attention and from the visual "setting up exercises" provided by the same pictures.

The optometrist or ophthalmologist whose help is sought as a result of discomfort experienced from viewing properly made stereoscopic motion pictures will make careful tests of the refractive condition of each eye, and of the functional pattern of seeing. His prescription may include simple or complex prescription lenses different for each eye, specifically designed for the condition of the individual. Such lenses may serve several very useful purposes. They may balance the acuity of the two eyes. They may also stabilize the accommodative-convergence relationship.

In addition, the professional man may prescribe a series of training procedures to teach each eye to function efficiently

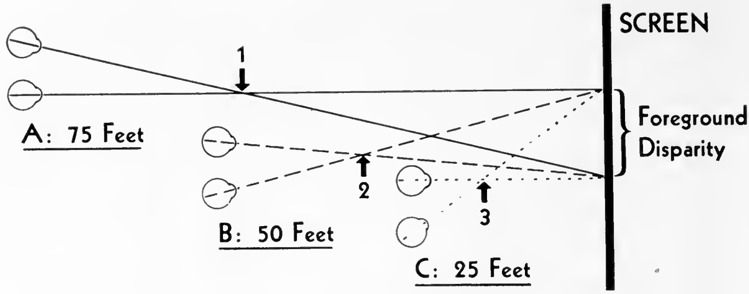


Figure 3

by itself. When this is accomplished he may then continue the training so as to teach the two eyes to function together effortlessly and skillfully. A part of this training procedure may well be the recommendation to see stereoscopic motion pictures periodically — once a day or once a week for example. It may be that he will recommend to his patient that he choose a seat in the front row for the first day and, as he improves in visual performance, that he move progressively back a row or two of seats, so that eventually he can sit in the rear row and view the full feature with comfort and satisfaction. For other patients he may reverse the prescription, suggesting that they start in the back row and periodically move closer to the screen.

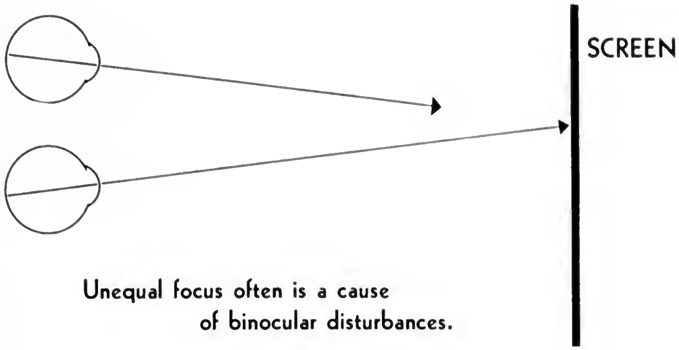
The disparity of the projected images of close-ups should not exceed 1/20 of the distance between the screen and the closest spectators. For example it should not exceed 12 in. in theaters where patrons will be as close as 20 ft from the screen. A foreground (crossed) disparity of 12 in., viewed from a distance of 20 ft will mean that the individual will need to converge as though looking at a point approximately 4 ft in front of him while still maintaining his focus on the surface of the screen 20 ft away.[20] The average person will be able to do this with ease provided such stimulation is momentary and infrequent. It would be difficult for most of us to maintain this convergence over a long period of time.

The close-up disparity can be increased or decreased in direct ratio to the distance of the nearest seats to the screen. As a further example, if the nearest point of observation from the screen is to be 30 ft, the foreground disparity can be as high as 18 in. and still remain within the range of tolerance of the average individual.

The background (uncrossed) disparity should not be more than $2\frac{1}{2}$ in. in pictures produced for entertainment. This holds true regardless of the size of the screen or of the distance from the screen to the audience. As the distance increases, however, the objectionable reactions of some individuals will be less, but the undesirable situation will still be there.

Consideration should be given to the various sizes of screens upon which stereoscopic motion pictures will be projected. The producer considers this variance in screen sizes in preparing the films for distribution.

Figure 3 shows the convergence required of three individuals sitting in a theater viewing a stereoscopic picture with a close-up (crossed) disparity of 6 in. — "A" sitting 75 ft from the screen, "B" 50 ft from the screen, and "C" 25 ft from the screen. The 6-in. foreground disparity will cause A, B and C each to see the object of regard at the point where



Unequal focus often is a cause of binocular disturbances.

Figure 4

the visual axes of each cross. C must converge over three times as much as A to fuse the two pictures.

Figure 4 illustrates the effect of background disparities on the accomodative-convergence relationship. Accommodation must be maintained on the surface of the screen while convergence relaxes. If the background disparities are greater than the interpupillary distances of the theater customers then an unnatural demand for divergence is made upon them. Such a demand is undesirable for the average individual.

Out of focus or "soft focus" photography should be avoided in all stereoscopic work. All details on the screen must be sharp and clear to avoid disturbances to the accommodative-convergence associations of the audience.

Let us take another example of a customer sitting in the middle of the theater 50 ft from the screen. This man has never had a professional eye examination. He has gone blithely along under the assumption that his vision was efficient because he was comfortable. The facts of the case are that his two eyes do not focus at the same plane. While one of them is looking at the screen, the other theoretically will be out of focus. In ordinarily occupations this person has learned to suppress mentally the vision of, say, his right eye. Had he not learned to do this at an early age he surely would have been uncomfortable because the images of the two eyes were not compatible. Confusion as well as discomfort would have resulted.

He puts on his polarizing spectacles. The powerful stimulus of a large stereoscopic picture with motion, sound and color, suddenly hits him. His habitually suppressing eye cannot ignore it. Confusion in his seeing, with resulting discomfort, begins to plague him. Surely he should not blame the producer, the exhibitor or the stereoscopic system. He is in need of visual attention, and the stereoscopic motion pictures should receive credit for identifying this need. Previously he was comfortable but inefficient in some of his visual skills.

The chances are nine to one in his favor that a visit to an ophthalmic practitioner will bring many benefits to him. After proper lenses have been fitted, one of these benefits should be the ability to view three-dimensional films with comfort and full appreciation of true stereoscopic seeing. The doctor may wish to prescribe frequent attendance at stereo features so that the two eyes will be further stimulated to work together as a team.

Stereoscopic motion pictures will bring to the public many benefits which go far beyond the entertainment factor. For example, facts gathered over the past 14 years of extensive research at Purdue

University under the direction of Joseph Tiffin, have demonstrated that our binocular seeing performance is related directly to out occupational performance.[11] Some of these relationships are:

1. Freedom from accidents.[4,5]

2. Productiveness.[6,7,8,17]

3. Freedom from discomfort on visual tasks.[7,8,17]

4. Accuracy in assembly, inspection and other fine work.[9,10,17]

5. Like, or dislike, of certain activities.[8,16,17]

Seeing is something we do. It doesn't just happen to us. It is a complex act and not a unitary function such as the ability to see clearly with each eye at a distance. Some of us see skillfully and well. Others do it clumsily and inefficiently. Some of us do it effortlessly while others do it with apparent difficulty and discomfort.[18]

Furthermore, seeing is different from other measurable human characteristics such as finger dexterity, temperament, motivation, intelligence or height and weight. Something can be done to improve it when it is below desirable standards. The ophthalmic practitioner can, in a high percentage of cases, transform inefficient, clumsy or uncomfortable visual performance into smoothly performing, effortless and skillful seeing. With the advent of stereoscopic motion pictures he will find facilities which will help him with many of these cases.

Fortunately for the segments of the motion-picture industry concerned with stereoscopic productions, the trend toward the diagnosis and treatment of binocular imbalances has proceeded at a very rapid rate during the past two decades. The benefits are not one-sided. Those pioneers in the ophthalmic field who long have recognized the importance of efficient binocular vision will now have a powerful ally to help focus attention on stereoscopic seeing. The public will be the beneficiary from this added attention to its visual needs.

This is the age of vision. It is the age of speed and precision. The work load has been lifted from men's backs and placed on their eyes. In our factories, offices and schools, and on our highways, the need is for visual skill and for judgment based on visual perceptions. We read gauges, make adjustments of delicate instruments, inspect through microscopes, move levers which guide rapidly moving machines. The task of reading reports and preparing blue prints is never done. The common laborer who can rely on casual vision is becoming rare. The farmer can no longer plod wearily behind the plow. He drives machines, keeps books. This is the age of TV and 3D.

The ophthalmic professions and the ophthalmic industry have met the challenge. As an example, Bausch & Lomb Optical Co. initiated research in the field of vision as it relates to our occupations, and established a research grant at Purdue University. The ophthalmic professions gave active support.[15] Managements of many of our leading industrial and commercial companies cooperated by testing the visual performance of thousands of employees on a large variety of jobs. They assembled measures of employee success, such as accident experience, records on absenteeism, hospital visits, tenure on the job, earnings, quality and quantity of work.[13,14] The statistical analysis of these data provided factual evidence to establish:

1. That stereoscopic testing instruments are necessary to provide an accurate profile of an individual's binocular performance.[12]

2. That stereoscopic factors of vision are important in our everyday occupations.[13,14]

3. That giving consideration to each eye independently, without also giving equal attention to how the two eyes perform as a team, can be unfair to the individual.[11]

Fig. 5. The Ortho-Rater: a stereoscopic instrument for testing visual skills.

The visual testing instrument that resulted from these extensive investigations was the Ortho-Rater (Fig. 5). It provides highly reliable tests of 12 of the most important visual skills.[12]

Instruments of this type are used widely in industrial and commercial companies, in the military forces, and other areas. When one thinks of the motion-picture industry, the question might well be asked, "Do all of the individuals concerned with the production and projection of stereoscopic films possess the visual qualifications which will permit them to handle the job most efficiently?" Tests such as are contained in the Ortho-Rater might provide revealing information.

It is conceivable that the use of an instrument of this type will enable one to predict the probabilities of an individual's sitting through a 90-min stereoscopic feature without apparent visual discomfort. On the assumption that such a visual standard could be established, we could then say that those who meet the standard could probably view the stereoscopic pictures without discomfort or effort, and that those who fail the standard should seek professional eye care for the sake of their own health and general well-being, even though they are not planning to view stereoscopic motion pictures. We also could tell them that, according to the laws of probability the chances are nine to one that they would be benefited by professional eye care. In addition, a small but very important percentage of those who fail to meet the standard, and who consult a professional man, will discover that the cause of their low visual performance is a pathological difficulty not originating in the eyes even though it reflects in impaired visual functioning.

During the period between 1850 and 1870, Dr. Oliver Wendell Holmes did much to popularize the stereoscope which

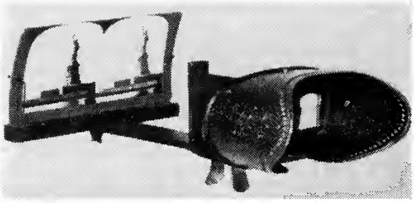


Fig. 6. The Holmes model of the Brewster Stereoscope.

bears his name (Fig. 6). This instrument occupied a prominent place on the parlor table of every cultured home at the turn of the century. In the *Atlantic Monthly* of 1859 Dr. Holmes wrote, "The Stereograph is to be the card of introduction to make all mankind acquainted." In response to this statement of nearly 100 years ago, some have smiled and said that Dr. Holmes did not foresee the impact of rotogravure, motion pictures, radio and television. Others today can smile and say that his prophecy is being fulfilled now that the stereoscope has come to motion pictures, and in the future may come to television.

Dr. Holmes saw the educational value of the stereoscope but he did not foresee it as a therapeutic instrument. Javal first used the stereoscope for the treatment of crossed eyes (squint) as as early as 1895.[22] Since that time it has been the accepted means for visual training (orthoptics). In fact, some form of the stereoscope is the only means known for developing good binocular habits in those individuals who have the basic ingredients for normal two-eyed seeing but who have not learned to use them efficiently.

Motion pictures greatly extend the use of the stereoscope in this important field. They remove one of the restraining barriers that have limited visual

Fig. 7. An Ortho-Fuser in use. The kit contains 5 vectograms of stereoscopic design, bound with instruction sheets in booklet form, and a pair of polarized spectacles.

training. Previously the monotony of the treatment and lack of interest on the part of the patient in viewing diagrams and charts in a stereoscope challenged the ingenuity, resourcefulness and patience of the practitioners and technicians. Now for the first time thrilling drama, with color and stereoscopic effect combined, can be used as a valuable supplement to the specific, controlled, clinical procedures in the professional office.

In view of the widespread use of stereoscopic testing and training instruments today, and in view of the imminent wide-spread use of stereoscopic motion pictures, we believe we can paraphrase Dr. Holmes' prophecy and state, "The stereoscope will be the card of introduction to make those who need visual attention acquainted with the ophthalmic professions."

When one considers the superb entertainment, educational, cultural and therapeutic values of properly produced, properly projected and properly viewed stereoscopic motion pictures, he can justifiably ask, "why should not every school child have the opportunity of viewing them periodically?" The powerful stimulus to better binocular vision will in this way be brought to the child during the formative years, while he is developing the pattern of seeing habits that may stay with him through life. Our first consideration, however, is to be sure that his *eyes are right*. The nation-wide showing of stereoscopic motion pictures will help to create the desirable awareness of the need for more attention to our children's vision. In consequence it will hasten the day when we can be sure that their vision is adequate for their various activities.

The educational job must not be a publicity program. It must be an orderly and constructive procedure that will earn the cooperation of the many strong allies who also are keenly interested in the success of the motion-picture field's program.

References

1. H. Grimsdale, "A note on Pulfrich's Phenomenon with a suggestion on its possible clinical importance," *Brit. J. Ophthalm., 9:* 63–65, 1925.
2. R. M. Hall, "Pulfrich's Phenomenon," *Am. J. Optom., 15:* 2; 42–46, Feb. 1938.
3. F. H. Verhoeff, "Effect on stereopsis produced by disparate retinal images of different luminosities," *Arch. Ophthalm., 10:* 640–645, Nov. 1933.
4. N. F. Stump, "A statistical study of visual functions and industrial safety," *J. Appl. Psych., 29:* 6; 467–470, Dec. 1945.
5. N. C. Kephart and Joseph Tiffin, "Vision and accident experience," *National Safety News, 62:* 90–91, Oct. 1950.
6. A. K. Peterson and Frank Noetling, "Preliminary report of progress of the eye programs at R. R. Donnelley & Sons," *Trans. Am. Acad. Ophthalm. and Otolaryng.:* 270–275, Jan.-Feb. 1950.
7. E. W. Howard, "Fulton study relates vision and efficiency," *Textile World, 99:* 97–99, July 1949.
8. G. W. Morgan and N. F. Stump, "Benefits from professional eye care for workers with lowered visual performance," *Trans. Am. Acad. Ophthalm. and Otolaryng.:* 99–105, Sept.-Oct. 1949.
9. Leon D. Gruberg, "Effects of a vision program in a TV plant," *Opt. J. and Rev. Optom., 89:* 36–37, Feb. 1952.
10. E. J. McCormick, "An analysis of visual requirements in industry," *J. Appl. Psych., 34:* 1; 54–61, Feb. 1950.
11. H. S. Kuhn, *Eyes and Industry*, 2d ed., The C. V. Mosby Co., St. Louis, 1950, pp. 53–71, 97, 108, 110, 145.
12. F. W. Jobe, "Instrumentation for the Bausch & Lomb Industrial Vision Service," *Bausch & Lomb Magazine, 20:* 1; 6–7, Feb. 1944.
13. Joseph Tiffin, *Industrial Psychology*, 3d ed., Prentice Hall, New York, 1952, pp. 194–241.
14. C. H. Lawshe, Jr., *Principles of Personnel Testing*, McGraw-Hill, New York, 1948, pp. 96–122.
15. R. A. Sherman, "Ophthalmic science and practice applied to vision in

industry," *Bausch & Lomb Magazine*, *20:* 1; 1–9, Feb. 1944.
16. N. C. Kephart, "Visual skills and labor turnover," *J. Appl. Psych.*, *32:* 51–55, Feb. 1948.
17. J. H. Coleman and Richard Feinberg, "Vision tests for inspectors insure good placement," *Factory Management and Maintenance*, *103:* 106–110, Jan. 1945.
18. C. F. Shepard, "Visual skills," *Optometric Weekly*, *34:* 1465–1466, Jan. 1944.
19. Julia E. Lancaster, *A Manual of Orthoptics*, Charles C Thomas, Springfield, Ill., 1951; *The Sight Saving Rev. of the National Society for the Prevention of Blindness*, *22:* 125–126, 1952.
20. J. A. Norling, "The stereoscopic art — a reprint," *Jour. SMPTE*, *60:* 268–308, Mar. 1953.
21. E. F. Tait, "Accommodative convergence," *Am. J. Ophthalm.*, *34:* 1093–1107, Aug. 1951.
22. James E. Lebensohn, "Louis Emile Javal, a centenary tribute," *Arch. Ophthalm.*, *21:* 650–658, Apr. 1939.

Discussion

Lt. Col. Robert V. Bernier (*U.S. Air Force, Wright Air Development Center, Dayton, Ohio*): Since, when we are looking at physical objects at say 10 ft, objects further in the distance appear relatively in focus, is it not true that we could have convergence up to a point 10 ft from our position in the theater and still be relatively focused for image matter on the screen without discomfort?

Mr. Sherman: Yes, if you mean that the camera can be as close as 10 ft; was that your point?

Lt. Col. Bernier: No, Sir, I mean if the displacement of images for the crossover, as you mentioned, was such that the convergence occurred at 10 ft from your viewpoint, as you're sitting in the theater, would not the subject matter or the image on the screen be in relatively good focus even though we were converged and accommodated for that 10-ft position? When we look at physical things in real life, 10 ft away, objects in the medium and far distance up to infinity appear relatively in good focus.

Mr. Sherman: Yes, I get your point. When you look at an object — suppose I look at Dr. Frayne, 10 ft away. I have to accommodate to see him sharply. I need to converge. I need to do both. Now, if I converged on Dr. Frayne and focused on the wall over there, which I am doing now, he's very blurred. Or if I converge on the wall and focus on Mr. Frayne, I see two of him. Is that bad?

Lt. Col. Bernier: No, I didn't mean that. I mean to imply that this thing of optical infinity, you consider what? 20 ft?

Mr. Sherman: Let's say 20 ft. 26 ft rather.

Lt. Col. Bernier: That means that for objects in physical life beyond 20 ft, everything as far as the individual is concerned is in focus regardless of where you are converged. Isn't that true? Then that would imply that in three-dimensional motion pictures you could have objects appearing as close as 20 ft from your position in the theater and still be in focus for the image which is on the screen.

Mr. Sherman: Yes. I think I get your point. The only difference is that I change both my accommodation and my convergence when I change fixation from a distance to him. However, if I were looking at a projected stereo picture taken of him with the camera placed where I am standing, my accommodation would need to be on the surface of the screen while my convergence is directed toward the picture in front of the screen. This would not be an undesirable situation and should cause no discomfort.

Charles Smith (*Stereo Techniques, Ltd.*): Dr. Sherman listed among his requirements for properly projected and properly produced pictures that on background objects the displacement of the two image points should not be greater than 2½ in., which causes the eyes to squint outwards. Now, as we know, on some of the pictures that we've seen this limit of 2½ in. is very greatly exceeded on background objects, with unpleasant results. I'd like Dr. Sherman to tell us whether he considers that in this case the results are actually harmful to the eyes, or merely unpleasant.

Mr. Sherman: They are only unpleasant. The eyes are not hurt by diverging. The physical eye cannot be hurt by viewing stereoscopic motion pictures providing there is no pathology that requires abstinence from normal seeing tasks. Discomfort is all that might be induced.

Edward Stanko (*RCA Service Company, Camden, N.J.*): Isn't it possible to overdo the stereoscopic effect? Recently I noticed that in some of the 3-D pictures they'll have a tree or some other object very close to the camera, then there will be a set 15 or 20 ft away, and then further back there will be a background scene. Now that's a considerable distance for the eye to cover. Do you think that sustained photography under such conditions might produce eyestrain?

Mr. Sherman: Yes, it might cause a little discomfort and particularly with those individuals who do not have adequate flexibility between the functions of accommodation and convergence.

Mr. Stanko: In regard to your suggestion that stereoscopic pictures are beneficial to the eye, I've had some personal experience with my own son. When he was a small boy he had one crossed eye. By using these stereoscopic pictures and eye exercises he was able to improve his vision considerably.

Mr. Sherman: Well, that's interesting. We should keep in mind that flexibility in visual functions can be developed through some of the stereo pictures which at first might cause some discomfort.

Nic Archer (*Univ. of California Student*): Do you consider the Viewmaster Stereo Viewer to be of an optical quality to be beneficial to small children?

Mr. Sherman: Those I have seen have been excellent.

Lawrence Brunswick (*Colorvision Inc.*): Following up Mr. Stanko's mention of the sets with the very great depth, I think that brings out the aspect that so much of our stereo work is done with too great an interpupillary distance between the two lenses, and that causes that great disparity. That has to be carefully watched, I believe.

Mr. Sherman: That's one of the points of properly produced stereo pictures that we have stressed in this paper. Yes, desirable interaxial distances in the stereo camera are an essential ingredient.

Dr. Feinberg (*Northern Illinois College of Optometry*): I wish you would amplify a comment you made about vertical imbalance or the effects induced by improper displacement vertically by the projectionist.

Mr. Sherman: There are 2% of us in this room, if we're average individuals, and I assume we are, whose right eyes tend to tilt upward; another 2% whose left eyes tend to tilt upward. If for example, the left-eye frame is higher on the screen than the right-eye frame, the 2% of us in this room whose left eye tends to tilt upward would have their condition eased while the 2% whose right eye tends to tilt upwards plus the 96% whose two eyes are in normal vertical balance would be penalized. I have a friend with a Stereo Realist camera and a 3D Stereo Projector. He has a right vertical imbalance and when we visit him he tries to project his pictures with the right-eye frame slightly higher because *he* sees them comfortably that way. For the sake of the 96% of the people who have normal vertical balance, let's keep the frames in synchronization in vertical alignment. Then the identifying finger is going to be on the 4% that ought to see some of these eminent professional men who are here this afternoon. Otherwise the other 96% are likely to go.

Mr. Stanko: Mr. Sherman, could you give a brief explanation of why a stereoscopic picture appears to be smaller the minute that you add depth to it? I've noticed that the large screens that were used in theaters, which apparently seem to be large for 2-D pictures, but the minute that you put a 3D picture on it, it shrinks right down and comes right to you and gets smaller. Can you give a brief and simple explanation of that?

Mr. Sherman: Very briefly, this phenomenon is in the field of our psychological factors of vision. We converge on an object when it is near to us. Interpretatively we think of it as being nearby and at the point where our visual axes cross. It's in the mind, strictly, and it's related to our convergence interpretations. The factors of convergence and accommodation control the suggestion of relative sizes.

John G. Frayne (*Westrex Corp. and Chairman of the Session*): I think that that question will be answered in more detail tomorrow afternoon in the paper by Dr. Hill of the Research Council.

Mr. Sherman: Dr. Frayne, may I make one other comment. Were we to get into the clinical aspect of visual performance and of how we see, I'm not the one who should answer that. Rather it should be the men in clinical practice who are in the audience. When it comes to the relationship between how we see, and how we perform at occupations we will try to answer questions.

Winton C. Hoch (Cinerama Productions): How much convergence disparity can your 80% of well-adjusted people accommodate?

Mr. Sherman: In a well-conducted clinical study of around 4,800 cases, Dr. Tait plotted the latitude between accommodation and convergence. It ranged all the way from zero — people who seem to have no latitude, at one extreme, to the other extreme where there was a very high latitude. In other words, with some individuals the stimulation to one function does not affect the other. But the average latitude is about 8 prism diopters. Now the recommendation that we made this afternoon that the crossed disparity — or near-point disparity — should not exceed 1/20 of the distance from the nearest spectator to the screen, requires only about 4½ prism diopters of latitude as we refer to it. So the limits I have indicated still leave an ample latitude between what 80% of the people have and the limits I indicated.

Mr. Hoch: Could you restate that in terms of an illustration? If a person were sitting in the middle of the audience, say 50 ft from the screen, how close could the image appear stereoscopically to him, and satisfy your requirement?

Mr. Sherman: Within 4 ft.

Mr. Hoch: That would apply to, say, 80% of the viewing audience?

Mr. Sherman: About 80% will have the visual mechanism and the performance to do that, providing it is not sustained, providing it's momentary.

Mr. Hoch: Then there is a time element also included?

Mr. Sherman: Oh, yes. If it were to be there for a minute or two at that one spot, why some people would feel it, even among the 80%. But if it's momentary there should be no problem.

Visual Monitor for Magnetic Tape

By ROWLAND L. MILLER

This monitor presents visually the information recorded on magnetic tape without employing auxiliary equipment such as movable scanning heads, amplifiers, etc. The presentation is a variable-area display that indicates frequency and amplitude. The display remains stationary as long as the tape is motionless in the Magnescope, but movement of the tape is accompanied by corresponding movement of the display. Magnescope consists of a unique cathode-ray tube and its associated power supply. The cathode-ray tube is so constructed that the magnetic fields from the tape directly influence a beam of electrons which produces the variable-area display.

THE MAGNESCOPE is a visual monitor for magnetic tape. It gives visual presentation of the information recorded on the tape without employing auxiliary equipment such as movable scanning heads, amplifiers, etc. The presentation is a variable-area display and thus gives indication of frequency and amplitude. The display remains stationary as long as the tape is motionless in the Magnescope, but movement of the tape is accompanied by corresponding movement of the display.

Magnescope consists of two units connected by a single cable (Fig. 1). One of these units houses a unique cathode-ray tube which produces the visual display. This unit is equipped with proper guides to accommodate various magnetic tapes. A hold-down mechanism is provided, which, in conjunction with the guides, assures correct positioning of the tape. Since this unit would normally be in front of the user it includes an On-Off switch, pilot lamp and fuse. The second unit is the power supply and includes all adjustable controls. Once the controls are adjusted for a particular cathode-ray tube there is apparently no reason for readjustment for the life of that tube. This unit normally rests on the floor or any other convenient place.

The cathode-ray tube which produces the display is similar in shape to electrostatic deflection tubes of comparable size. At one end of the tube is a gun structure. At the other end is a medium persistence screen. In between these extremities is a metallic section about 4 in. long which makes the operation of the tube possible.

The gun structure consists of a heater, cathode, grid and first accelerating anode and, as in conventional cathode-ray tubes, the structure supplies the electrons and shapes them into a suitable beam. The potentials on these various elements

Presented on April 30, 1953, at the Society's Convention at Los Angeles by Rowland L. Miller, Magnescope Corp., 1147 N. McCadden Pl., Hollywood 38, Calif. (This paper was first received on March 25, 1953, and in complete form on July 29, 1953.)

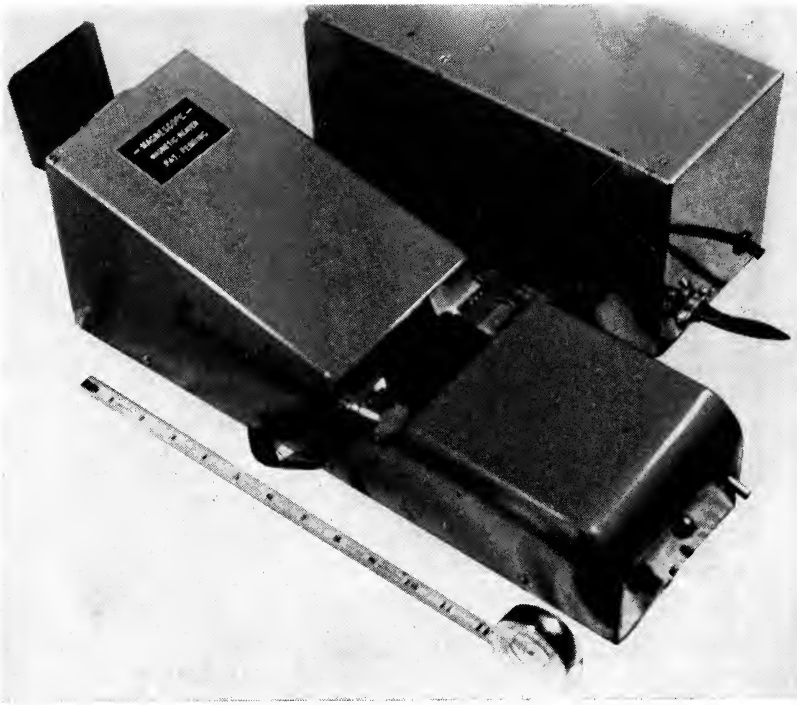


Fig. 1. Experimental demonstration model of the Magnescope.

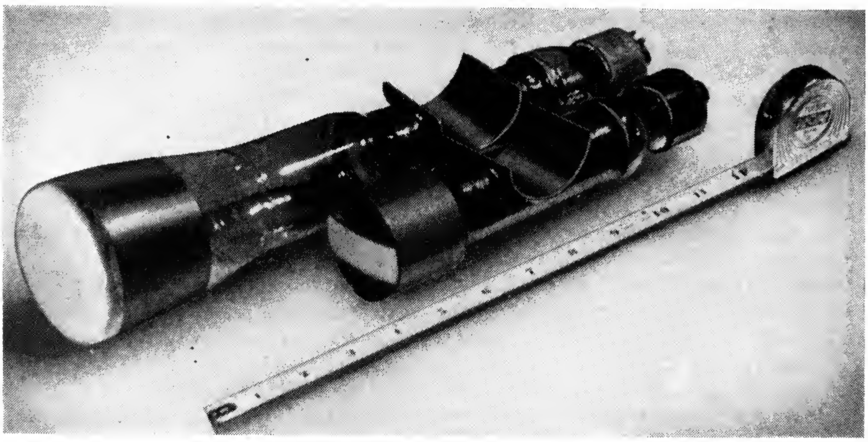


Fig. 2. 2-in. and 3-in. tubes. The second anode and saddle can be seen near the center of each tube.

are adjusted so that the electron beam leaving the gun structure is cone-shaped, with the apex of the cone at the first anode.

The forementioned metallic section near the center of the tube is the second anode, which is specially designed and serves several functions. It positions the tape (in conjunction with the guides and hold-down mechanism), forms the electrons into a properly shaped beam, and accelerates the electrons toward the screen after they have been deflected by the magnetic fields of the tape. Near the center of the anode and at right angles to its axis there is a cylindrical trough known as the saddle. Figure 2 shows the second anode and the saddle. In the bottom of this saddle is a thin window of nonmagnetic material. When the Magnescope is in use the magnetic tape passes through the saddle with the recorded area directly against the window. The magnetic tape, therefore, passes through the saddle and at right angles to the axis of the tube.

The cone-shaped beam of electrons entering the second anode is formed into a ribbon-shaped beam by suitable elements in the anode and the electrons in this ribbon pass directly underneath the window in the saddle. The potential on this anode is such that the electrons are accelerated toward the screen. The electrons, upon striking the screen, produce an illuminated band across the center of the screen which is parallel to the window. In the absence of magnetic tape in the saddle the electrons travel in trajectories which are determined by the beam-forming elements only and pass through the tube to form the illuminated band as outlined above. However, when the recorded area of the tape is placed at the window in the saddle the magnetic fields surrounding the tape extend through the window and into the ribbon of electrons directly below. The introduction of these fields changes the trajectories of the electrons and the upper edge of the illuminated band is now distorted. The amount of distortion is a function of the size and strength of the individual fields.

It is not the purpose of this paper to analyze the magnetic fields produced by the recording on the tape, but the track acts almost as if it consisted of very small magnets placed laterally across the track area and adjacent along its length. Continuing this analogy further and considering a single frequency only, each magnet would be magnetized and have a dimension of one-half wavelength in the longitudinal direction of the track. Furthermore, the magnets would be placed with like poles adjacent. Each magnet (half-wavelength) would have a closed external magnetic field between its poles, but, due to the placement of the magnets with like poles adjacent, the directions of these fields will be reversed for consecutive magnets. Thus there is a reversal of field for each half-wavelength.

As the electrons enter these fields they are deflected toward the tape or away from it, depending upon the direction of the magnetic field. Since the electron deflection is always normal to the direction of the field, the deflection upward and downward will not be symmetrical about an axis. The reason for this is that for a recorded sine wave each half-wavelength field acts as if it were approximately semicircular in shape. For a field direction which deflects the electrons away from the tape, the electron deflection assumes this semicircular shape and the bottom half of the cycle is approximately semicircular. For the other half of the cycle where the field direction is such that the electrons are deflected toward the tape a different situation exists. Because the deflection is normal to the semicircular field the electrons are deflected toward the center of the field as well as upward and this half of the cycle assumes a spike shape.

The net result of this is that for recorded sine waves the display is a series of cusps — one for each cycle. This effect diminishes with decreasing frequency

Fig. 3. 100 cycles/sec as seen on the Magnescope. The recording circuit was turned on at the peak of the cycle (left side).

and at frequencies of 100 cycles/sec or less the display assumes a sine-wave shape (see Fig. 3). At frequencies of several thousand cycles/sec the display appears almost as a series of spikes. This effect is not detrimental to the purpose for which the tube is intended, however.

The area scanned at any one time is slightly more than one frame. The limit of resolving power is about 6000 cycles/sec for a 3-in. tube. The amplitude of the display is about $\frac{3}{8}$-in. for a 100% modulated track. A signal 30 db below 100% modulation can be seen.

Experimental tubes with 2-, 3-, and 5-in. screens have been made. In each case the geometry of the gun structure and second anode is identical. The 2-in. tube is about $8\frac{1}{2}$ in. long and is intended to be adapted to existing film editing machines to give visual monitoring for film editors. The 3-in. tube has applications outside of the motion-picture industry. The 5-in. tube was developed for research in cardiology. In each case one frame covers the face of the tube. The tubes will handle all existing track including the "three strip."

Only experimental tubes have been made up to the present time and the 3-in. tube has been incorporated into the Magnescope for display and demonstration purposes. The final form of the Magnescope has not been determined. The needs of the industry must be served and these needs will determine its final outcome.

Discussion

George Lewin (*Signal Corps Pictorial Center*): Have you given any thought to making the track that you're looking at audible at the same time, so that it would be an additional help to editing?

Mr. Miller: Yes, we have. However, this tube is a static device as well as a dynamic one. In other words, the display is visible when the track is motionless and you see a variable-area picture on the tube of what's recorded on the track. Now the disadvantage of coupling this directly to some audible reproducer is the fact that for audible reproduction the track must be moving, which, in a sense, defeats the purpose of the tube.

Mr. Lewin: Can't you pick up the beam just as you pick up the scanning beam in an iconoscope and just the part that's stationary would then be repeated over and over again if you scanned it slowly enough? If you could scan at the speed corresponding to its normal tape motion, then it ought to give you an intelligible reproduction of the particular syllable or words that are in the aperture at that moment.

Mr. Miller: Yes. You mean incorporate a photoelectric cell into the beam somehow. Is that what you meant?

Mr. Lewin: Either that, or the beam itself could be fed into a tube, and amplified as it's scanning so as to give you an audible signal, provided the scanning is kept down to about the speed of the normal tape motion.

Mr. Miller: Yes, that could be done, except that there again the tape must move at some speed, the speed at which it was recorded and when that happens, you will not see the pattern of the tape. The tube was made to find footsteps, all kinds of sound effects, beginnings and endings of music and words and blank spaces. If the tape moves slowly through the tube you can see all of those things. If you move the tape at the speed at which it was recorded in order to reproduce it, then the tube is ineffective. Do you see my point?

Mr. Lewin: Yes, I see your point. It's entirely possible that what I have in mind is impossible to accomplish. What I picture in my mind is that you have this electron beam scanning across, say, a short piece of the tape.

Mr. Miller: It's continuous. The electron beam is a solid ribbon of electrons that goes directly beneath the tape and is about a frame wide. There is no scanning.

Mr. Lewin: I see. I thought it was the electron beam scanning across it.

Mr. Miller: No. We tried using a beam and scanning but the resolving power was not good, so we gave that idea up.

Mauro Zambuto (*IFE Studios, N.Y.C.*): I would like to know what happens when this gadget is used in connection with multiple tracks? Because if I understand it correctly, the direction of motion of the electrons in the beam is across the width of the tape. Therefore if we have a tape that has three tracks, one beside the other, the beam would be modulated in sequence by the signals of each of these tracks so that we would have practically a mixed signal of the three tracks.

Mr. Miller: This is a curved section (the saddle) and the film follows that curve. Now, the track that you are interested in is placed directly over this window. The other two are far enough removed so that they do not deflect the electron beam. Then to see either of the other two tracks you merely need to re-position the tape to select the track you desire to see.

Mr. Zambuto: That means that the active part of the tube is limited to about 100 mils or less.

Mr. Miller: That's right.

Mr. Zambuto: What is the order of magnitude of the accelerating voltage in the tube?

Mr. Miller: You mean the speed of the electrons?

Mr. Zambuto: That's right. I mean first of all the speed of the electrons near the window, and then the speed of the electrons when they hit the screen. Is there any difference between the two?

Mr. Miller: They move slowly in this region (near the first accelerating anode) and then are accelerated after deflection.

Mr. Zambuto: So the main acceleration would happen after this deflection?

Mr. Miller: That's right.

Mr. Zambuto: May I ask the order of magnitude again?

Mr. Miller: They hit the screen with a velocity of about 20,000 to 25,000 miles per second and in this region near the saddle they're traveling about 4000 miles a second. If you're interested, a 100% track, according to calculations, has an external magnetic field of about 1.6 gauss.

Mr. Zambuto: Exactly 1.6 gauss?

Mr. Miller: That's what it's calculated to be.

Mr. Zambuto: By external field you mean field at the surface of the window?

Mr. Miller: That's right.

Mr. Zambuto: And, of course, there is something to keep the film in close contact with the window?

Mr. Miller: That's right. There is a hold-down mechanism plus some guides that rotate and have proper width slots to select films of various widths.

Mr. Lewin: Is there any clear indication that can be seen in the display when 100% modulation or any specific level on the tape is attained? What I'm thinking of is whether it can be used to tell how near your are to the overload point of the tape.

Mr. Miller: 100% modulation of the tape has been arbitrarily defined as the point where 12% intermodulation is present when the track is reproduced. That has been called 100% modulation and represents a certain amount of audio power into the recording head. However, this power can be exceeded considerably without getting too much additional distortion. Due to the latitude of the tape, it is impossible to determine 100% modulation precisely by observation. However, if you just keep putting on more and more level you will come to a point where the film evidently becomes saturated, but that is way above what is called 100%.

Mr. Lewin: Do you foresee any possibility of modifying the tube so the display would look like a sine wave?

Mr. Miller: That's very difficult to do. In fact, Dr. A. M. Zarem has asked the same question but it's an extremely difficult problem. In fact, it may be impossible.

Francis Oliver (*Imperial Productions*): Could you tell me what order of magnitude of wavelength the tube would be able to stand?

Mr. Miller: At a speed of 90 fpm, which is standard motion-picture speed, the resolving power is about 6000 cycles. Now if the film is recorded at a slower speed, say at 45 fpm, the resolving power would drop down to approximately 3000 cycles. This is not a deficiency in the tube. It's a deficiency of the eye. You just can't see the spikes because they're beyond the human resolving power.

Mr. Oliver: Would there be a possibility of spreading this out or magnifying it electronically so it could be seen?

Mr. Miller: Yes. In fact, we made a 5-in. tube which is being used for research in cardiology. Just make the screen larger and the tube correspondingly longer and the resolving power goes back up.

Mr. Oliver: I don't know if your company has thought about it or not, but the computer field probably would have some interest in this for read-out equipment to display magnetic pulses. That is why I was interested in the magnitude of wavelength — would you estimate 2 mils, 3 mils, 8 mils in length?

Mr. Miller: Let's see — 6000 cycles is what in terms of 90 fpm?

Mr. Oliver: A mil and a half, something like that.

Mr. Miller: If you use that as a basis . . . .

Mr. Oliver: You say 9000?

Mr. Miller: 6000. Now 7000 and 8000 are on the tube, but you can't see them with the naked eye.

Mr. Oliver: Well then, you'd say that it will resolve, say, 7000 or 8000, and then we could magnify it so that we could actually display it?

Mr. Miller: That's right. You could do that.

C. E. Cunningham (*U.S. Navy Electronics Lab., San Diego, Calif.*): So far the device described is a qualitative device. Do you hope you can make quantitative measurements with it? That is, will you have a calibration scale on the front of the tube?

Mr. Miller: Yes, a calibration scale can be put on it, both in terms of frequency and in terms of amplitude.

Mr. Cunningham: Secondly, what about dynamic range? Will it cover the full dynamic range of the tapes now in use?

Mr. Miller: Well, the tube will go up to 8000 cycles. It is fundamentally an electron microscope, and the thing that limits its resolving power is the screen material. At about 8000 cycles the deflections are comparable to the size of the material of which the screen is composed and the resolving power then disappears.

Mr. Zambuto: I wanted to know whether varying the wavelength affects the vertical displacement of the beam on the screen, my point being that very high frequencies on a tape produce a field that is much closer to the tape surface than the field produced by a low-frequency signal. Does that influence the displacement of the electrons?

Mr. Miller: Yes it does. For 100% recorded levels at all frequencies the amplitude is greater at low frequencies than at high frequencies.

Mr. Zambuto: Then it seems to me that that would be the element limiting the frequency response of the apparatus. Because, granted that you can spread the beam horizontally by an electronic device, you would still be limited by the maximum vertical displacement that you can get out of a certain wavelength.

Mr. Miller: That is true, but you will still get a usable vertical displacement up to 8000 cycles and then the distance between the wavelengths becomes comparable to the particle size that makes up the screen. Now, by making a longer tube and getting effective magnification in both directions, vertical and horizontal, then you can go on up in frequency.

Mr. Oliver: Could you tell me the diameter of the scanning beam — the electron beam?

Mr. Miller: There's a continuous ribbon of electrons about a frame wide in the horizontal direction and about ⅛in. thick in the vertical direction, and the tape rides across the top of that ribbon and deflects the upper edge.

Westrex Film Editer

By G. R. CRANE, FRED HAUSER and H. A. MANLEY

This paper describes a film-editing machine which employs continuous projection resulting in quiet operation. It accommodates standard-picture and photographic or magnetic sound film as well as composite sound-picture film. Differential synchronizing of sound and picture while running, automatic fast stop and simplified threading features in the film gates with finger-tip release materially increase operating efficiency.

The Westrex Editer has been developed to provide facilities for editing 35mm motion-picture film, in a single integrated unit, for meeting the various and often conflicting requirements of the motion-picture field. The unit described in this paper is the result of extensive field surveys supplemented by consultations with many members of the film-editing profession in Hollywood. Noteworthy among the many improvements offered by this machine is the elimination of noisy operation by the use of continuous optical projection and the substitution of timing belt drives for gear-driven mechanisms.

It was generally accepted that the picture should be projected from the rear on a conveniently located screen and should be visible through a fairly wide viewing angle and with sufficient screen brightness to permit operation in a normally lighted room. It is felt that this has been accomplished to a very satisfactory degree. In addition, means have been provided for projecting an enlarged picture on a wall, the projection distance and resultant picture size being accommodated by the selection of a simple spectacle lens. Considerable attention has been given to simplicity and efficiency in operation and to the convenience of the operator. Threading of film has been reduced to a minimum of effort. Placing the film in the film trap automatically locks the film to the drive sprocket so that the position of the film cannot be lost inadvertently. Closing the film gate completes the operation. Removal of the film is accomplished with one sweeping motion of the hand. As the hand approaches the film, a flat lever is depressed which completely releases the film. The hand continues in the same direction and removes the film. Touching a different lever opens the film gate without releasing the film from the sprocket to permit the film to be inspec-

Presented on April 29, 1953, at the Society's Convention at Los Angeles by G. R. Crane (who read the paper), Fred Hauser and H. A. Manley, Westrex Corp., Hollywood Div., 6601 Romaine St., Hollywood 38, Calif.
(This paper was received on June 5, 1953.)

ted or marked without possible loss of its position in the film trap.

A differential synchronizer permits the position of the sound film to be continuously changed with respect to the picture film while the machine is either in motion or at rest. Associated with the differential synchronizer is a dial which counts the number of frames required for synchronism in either direction.

The sound sprocket is driven by a substantially constant-speed motor which is controlled by a foot-pedal switch operated by the left foot. The picture sprocket is driven by a variable-speed torque motor which is controlled by a foot-pedal switch and rheostat operated by the right foot. The film sprockets can be operated independently by their respective motors, or the two sprockets can be mechanically interlocked by the operation of a lever and driven by either motor in the forward or reverse direction. Four illuminated arrows indicate whether each motor circuit is set for forward or reverse operation and a fifth arrow indicates whether the two sprockets are interlocked.

General Description

Figure 1 is a front view of the Editer. The main housing is an aluminum casting which is supported by two formed sheet-metal legs. The height is adjustable over a range of 5 in. to accommodate the operator in seated or standing position. The two foot pedals are also adjustable back and forth to suit the operator. Four castors provide mobility while two jack screws insure operation in a stationary position when desired. The large raised section at the center of the main casting houses the viewing screen and two of four take-up spindles which are optional accessories for operation with 10-in. film reels. An incandescent lamp, located within this housing and operated by a push-on, push-off button

Fig. 1. Front view showing operation with film reels and bag at the rear for collecting film if reels are not used.

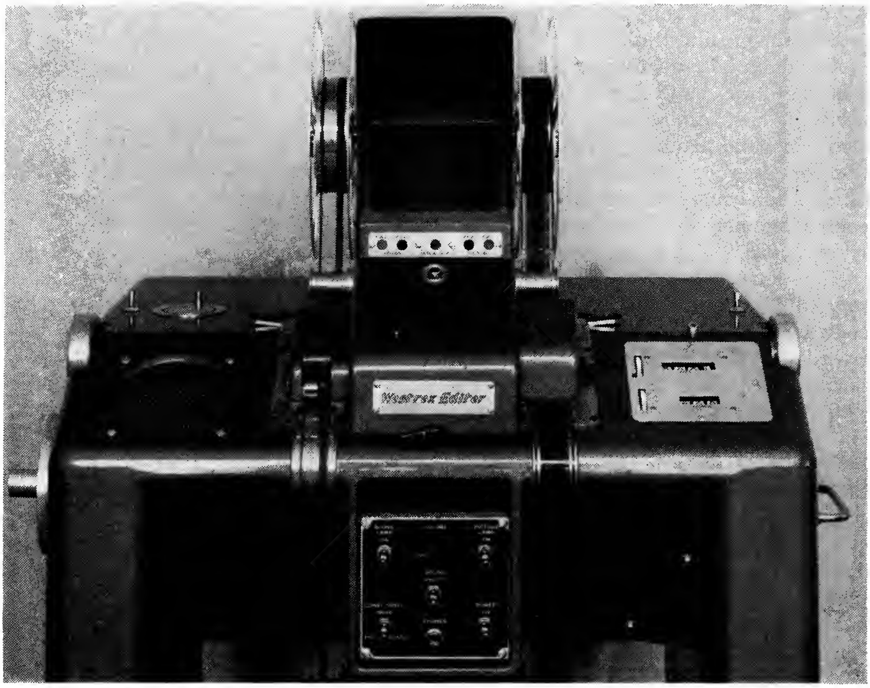


Fig. 2. Close-up of front showing operating controls.

switch, provides a shadow box for viewing film. The hood over the viewing screen is useful where a high level of room lighting exists, but is readily folded back or removed.

The lower take-up assembly between the legs is likewise optional and not present if operation without reels is desired.

A sheet-metal box connects the two legs at the rear near the floor, which provides structural stiffness and convenient housing for most of the electrical components. A removable rear panel gives ready accessibility to fuses, relay and amplifier. All wiring to the upper housing passes through plug connectors.

Controls

Figure 2 is a close-up view of the main housing showing the location of the parts of the equipment and the controls which are used in normal operation of the Editer. The center section starting from the top contains the viewing screen, the five indicator lights, the light-box lamp switch and the circuit control panel. This panel is equipped with sound and projection-lamp switches, a photographic-to-magnetic sound-transfer switch, a switch which operates the constant-speed motor or transfers the control to the foot pedal, a main power switch, a volume control and a jack for phones. To the left of the center section are the reversing switch and handwheel for the constant-speed motor and the differential-synchronizing control. In front of these is the monitor loudspeaker. To the right of the center section are the reversing switch and handwheel for the variable-speed motor, and the framing control. In front of these is the footage counter reading in feet and frames. An optional, additional counter reading sec-

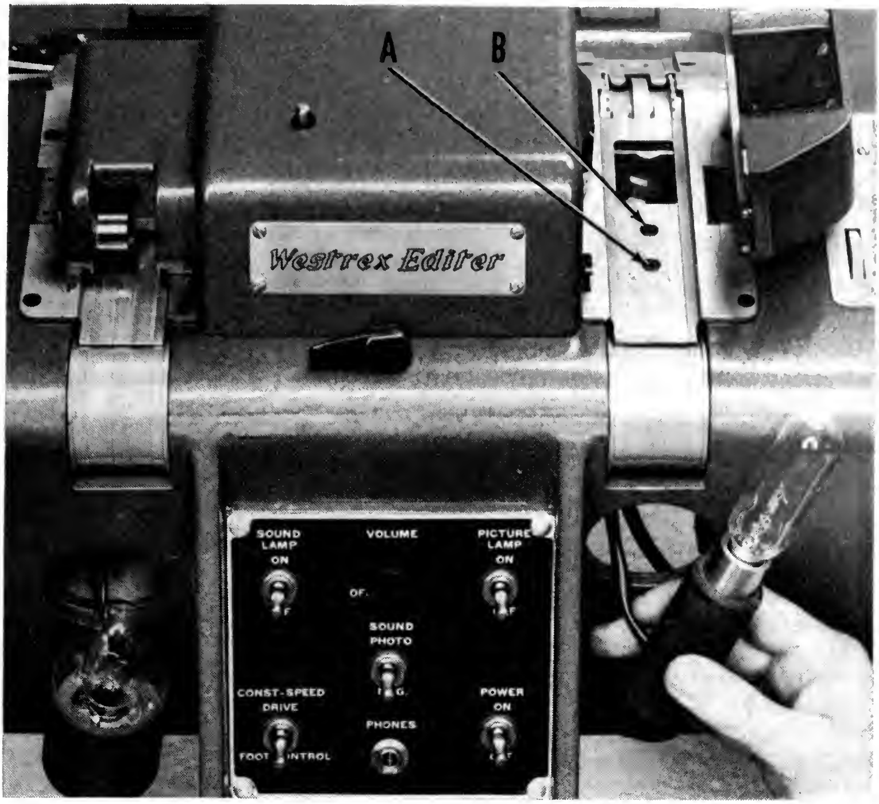


Fig. 3. Close-up showing removable, prefocused lamp mounts.

onds of time is mounted just below the footage counter. The sound and projection lamps are mounted in cartridge-type lamp mountings which are quickly removable from the front of the machine for replacement of lamps, as shown in Fig. 3. Both holders are keyed for registration and held by detents so that no tools or readjustments are required.

Just above the control panel is a lever which rotates through 180° to interlock the sound and picture drive mechanisms. It operates a coupling consisting of an internal gear meshing with an external gear of the same number of teeth, and a one-tooth interval in mesh is equivalent to one sprocket hole. The engagement is spring loaded by the control lever and the indicator light is lighted only when actual mesh is achieved, which may require the rotation of one shaft by a fractional tooth pitch. A high-speed rewind flange is located on the left side of the machine and is normally operated by the constant-speed motor. Several features of the Editer are sufficiently interesting to merit a more detailed description.

The picture system employs continuous projection by means of a rotating 12-sided prism, thus eliminating the noise introduced by the conventional type of intermittent movement. The picture image is projected from the rear on a translucent screen with sufficient light intensity to permit operation in the presence of normal room illumination. The image is $3\frac{3}{4} \times 5$ in. of the same

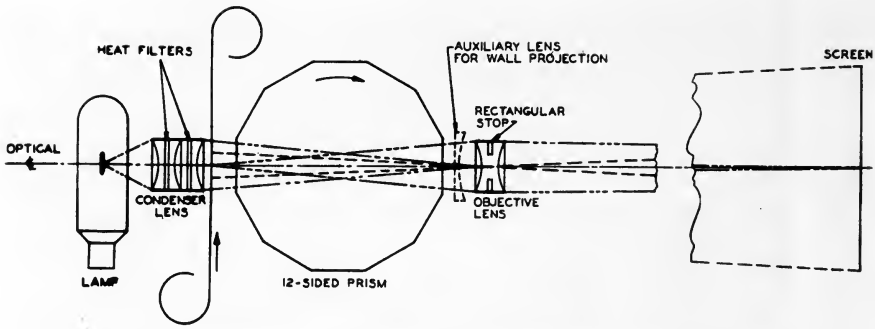


Fig. 4. Optical schematic, simplified by the omission of several mirrors.

orientation as the image on the film; that is, the film in the gate is threaded so as to appear upright and properly oriented from left to right and this relationship is maintained in the projected image on the screen. The quality of the image is comparable to that obtained with intermittent-type systems. The movement of a lever shifts the picture to the right enough to include a view of the sound track of a composite print.

If desired, an enlarged image can be projected on a wall or screen by operating two controls. A knob control inserts a simple spectacle lens in the optical path below the projection lens and a second knob tilts one mirror. This supplementary lens is introduced to focus the projected picture without disturbing adjustments of the normal optical system, and its focal length may be chosen to accommodate any given distance. In this case the orientation of the projected image is also the same as that of the image in the gate. The image size is a function of the distance between the machine and the screen, and for a distance of 10 ft the picture is approximately 15 × 20 in.

Optical System

The continuous-projection optical system is shown schematically in Fig. 4. The filament of the projection lamp is imaged in the objective lens by a three-element condenser lens. Two heat-absorbing filters are located between the elements of the condenser lens, and these filters are sufficiently effective to permit the film to remain stationary in the picture gate for an indefinite period without causing damage to the film. A blower passes sufficient air over the lamp and condenser-lens assembly to remove heat and keep the entire assembly cool. A mirror in the picture gate bends the optical axis at a right angle and directs it through a rotating 12-sided prism. A second mirror deflects the light beam into the objective lens which focuses the film image on the viewing screen. Two additional mirrors (not shown in the schematic) fold the beam for convenience. The prism is driven directly from the picture-sprocket shaft by right-angle helical gears. Framing is accomplished by sliding the drive gear along the shaft to alter the angular relationship between the prism and the sprocket. Several refinements in design reduce gear backlash to a minimum to insure picture steadiness.

The function of the prism in this system for continuous, nonintermittent projection is similar to systems employed in high-speed cameras and projectors, and the fundamental design considerations have been well covered in previous articles[1] and will, therefore, not be repeated here. The authors also acknowledge the significant contribution of L. B.

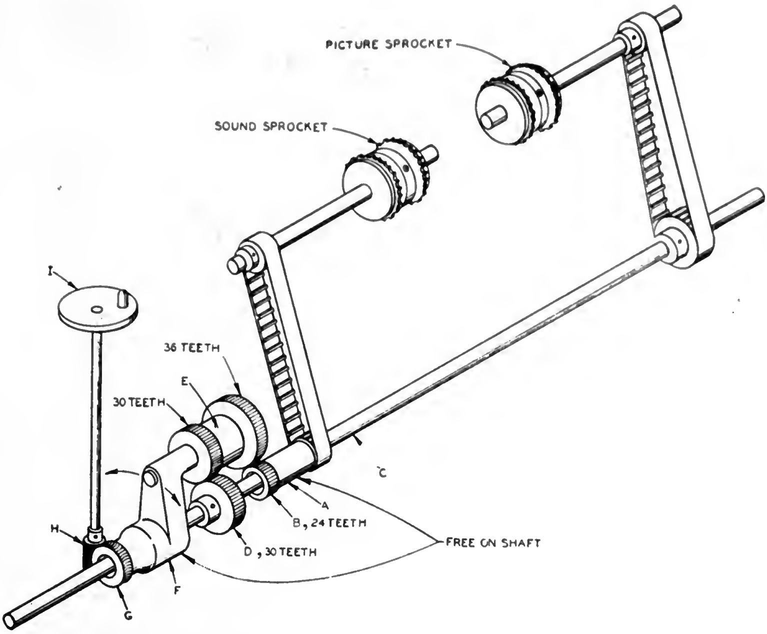


Fig. 5. Simplified mechanical schematic to illustrate use of epicyclic gears to permit changing the position of one film sprocket relative to the other.

Browder in the design of this optical system.

The various considerations of performance and manufacture indicate that the best compromise is a prism having 12 faces. Each face is active for a total rotation of the prism of 30° or plus and minus 15° from normal, plus the angle subtended by the objective-lens aperture. This aperture takes the form of a slit with its long dimension parallel to the axis of the prism to keep its subtended angle at a minimum, consistent with reasonable light conservation. However, due to this aperture effect, successive frames are projected as lap dissolves, the overlap being of short duration, representing the time required for the edge between two prism faces to pass across the effective width of the lens aperture. The prism is shown in Fig. 6 with the adjacent mirror D which turns the axis downward through the objective lens. This mirror is rotatable between stops to shift the image for viewing the sound track. The shift lever is shown as E.

Synchronization Control

Differential synchronization between the sound and picture films is accomplished by a series of gears on the jack shafts in the sound and picture film drives. With the two shafts interlocked, synchronization may be changed by indicated amounts while the machine is in operation or at standstill. Figure 5 is a simplified mechanical schematic of the differential synchronizer. A represents the sound jack shaft on which a gear B is mounted; C represents the picture jack shaft on which a gear D is mounted. The gears B and D are coupled through an integral pair of epicyclic gears E, the shaft of which is mounted on the carrier F. This assembly floats on the jack shaft and may be rotated about it by the

Fig. 6. Close-up of picture film trap, showing method of threading film.

worm and gear H and G and the manual indexed control I. The pair of epicyclic gears have different gear ratios and in consequence, when the carrier is rotated about the jack-shaft center, the sound film is advanced or retarded with respect to the picture film.

Film Traps

Figure 6 is a view of the picture-film trap and gate and illustrates the method of threading. The film is held between the two hands and laid in the film trap under light tension to sense the engagement of the sprocket teeth with the holes. The thumb is then in a position to press the film down and operate a trigger button shown at A which causes two film-retaining slides to move over the edges of the sprockets and retain the film in engagement. One of these slides may be seen as B. Closing the gate F completes the threading. The latter is held closed by the lever G, which may be operated at any time to release the gate but not the film-retaining slides. This permits ready access to the full area of the film for marking without losing synchronization. Depressing the upper lever C opens the gate and releases the film simultaneously.

For synchronizing purposes, the handwheel is turned to index any one frame with a reference arrow located in the center of the picture aperture, the arrow also being projected onto the viewing screen. The picture gate contains only a mirror for bending the light path. As shown by Fig. 3, the single screw A permits removal of the entire lamp mounting assembly, and the screw B releases the complete condenser and heat filter assembly for cleaning.

Sound Reproduction

The quality of reproduced sound is considerably better from the standpoint of frequency characteristic, signal-to-noise ratio and flutter than that which is usually associated with film-editing devices. The optical-scanning system is substantially the same as that in general use in theater reproducers. The magnetic head is a conventional commercial type. A four-stage amplifier is used for photographic sound reproduction and one additional stage is connected for magnetic reproduction with magnetic-reproducing equalization provided. The photographic input circuit contains a narrow dip filter tuned to 120 cycles to attenuate the light modulation resulting from operating the sound lamp on a-c. This feature combined with the relatively high thermal inertia of the 7.5-amp lamp gives a saitsfactory signal-to-noise ratio for this use. A tone control is provided on the amplifier and its knob appears through the top of the equipment box. An output jack is also provided at this point to plug in an extension speaker to be used with wall projection if desired.

Motors

The picture film is driven by a variable-speed torque motor which in combination with the foot-pedal resistance control is capable of driving the film at variable speeds from essentially standstill to double normal speed and is instantly reversible while running.

The sound film is driven by an induction motor, which is substantially constant speed, and is equipped with an electrical brake. A circuit is arranged to charge a condenser with rectified a-c from the line. When the foot pedal is released, back contacts on the switch connect the charged condenser to a relay coil and operate it for a short interval which is determined by the discharge rate of the condenser and the associated circuit. The relay momentarily connects a second charged condenser across the field winding of the motor, and, depending on the adjustment of a current-limiting resistor, the motor can be stopped within two picture frames. This type of braking is fully automatic and has the advantage of having no braking torque applied when the machine is turned by the handwheel.

In conclusion, it is felt that the Westrex Editer will fill a long-existing need of the motion-picture industry for modernized film-editing facilities with increased efficiency and improved convenience in operation.

References

1. F. Ehrenhaft and F. G. Back, "A non-intermittent motion picture projector," *Jour. SMPE, 34:* 223–231, Feb. 1940.
2. F. Tuttle and C. D. Reid, "The problem of motion picture projection from continuously moving film," *Jour. SMPE, 20:* 3–30, Jan. 1933.
3. Howard J. Smith, "8000 pictures per second," *Jour. SMPE, 45:* 171–183, Sept. 1945.
4. J. Kudar, "Optical problems of the image formation in high-speed motion picture cameras," *Jour. SMPE, 47:* 400–402, Nov. 1946.
5. J. L. Spence, "An improved editing machine," *Jour. SMPE, 31:* 539–541, Nov. 1938.
6. John H. Waddell, "Design of rotating prisms for high-speed cameras," *Jour. SMPE, 53:* 496–501, Nov. 1949.
7. Charles W. Wyckoff, "Twenty-lens high-speed camera," *Jour. SMPE, 53:* 469–478, Nov. 1949.

A Nonintermittent Photomagnetic Sound Film Editor

By W. R. HICKS

The editing of magnetic sound tracks by visual and aural methods has become increasingly important because of the rapid adoption of the magnetic system by the industry, both for primary recordings and theater release. Three-dimensional theatrical and multicamera television films have also stressed the need for editors which show more than one picture. A solution is suggested for these problems and a system of electronic editing is proposed, leading to an enlargement of editing processes to include sound recording, re-recording and dubbing, formerly limited to the sound studio.

THE DEVELOPMENT of magnetic sound recording has greatly influenced the technical handling and treatment of sound tracks following the general acceptance of the magnetic system by motion-picture producers. Initially, the magnetic track was approved for primary recordings because of its high signal-to-noise ratio, low distortion and ease of playback. But invisible magnetic tracks were impossible to edit by conventional sight methods, and magnetic recording required transfer to photographic tracks for subsequent editing, mixing and release on photographic equipment. Various systems for visualizing the recorded magnetic track were tested to facilitate direct track editing. Some early methods featured the use of magnetic inks and wet solutions containing carbonyl iron, but these were in general awkward and sometimes messy and were superseded by auxiliary visual track systems, including a combination of parallel magnetic and photographic sound tracks or companion inked tracks traced directly on the magnetic film, this system being known as modulation writing.

With these aids the motion-picture editor now cuts and assembles magnetic tracks in much the same manner as photographic tracks, on familiar equipment adapted for magnetic-track scanning. Editing by sight methods, he depends upon his magnifying glass or optical loop, but he must still check finished cuts audibly on machines with low-quality sound-reproducing elements and high flutter and mechanical noise. The word endings of a photographic track or visualized magnetic sound track are not easily seen when the frequency is high and modulation low. Cutting errors often result which are difficult to detect audibly on small loudspeakers and amplifiers of limited frequency range and when mechanical noise reduces intelligibility. Later listening under the high-quality conditions of a mixing room or theater often discloses missing

Presented on April 29, 1953, at the Society's Convention at Los Angeles by W. R. Hicks, Centaur Products Corp., Manhasset, N.Y. (This paper was first received May 5, 1953, and in revised form July 2, 1953.)

"ess" sounds, faultily de-blooped splices and unwanted stage background noise. In many cases, after preliminary rehearsal a reel with its multiple sound tracks must be returned to the cutting room for further work.

For critical listening the editor needs equipment with performance at least comparable to the machine and electronic elements of the mixing room. This is especially true when auxiliary sight-cutting tracks are unavailable because of added cost, and the invisible magnetic track must be edited directly by listening methods alone.

The editor described has been designed to meet these requirements. Mechanical noise has been reduced by minimizing gear components. Uniform film motion with low flutter is stressed, and the reproducing amplifier, power supply and loudspeaker system are

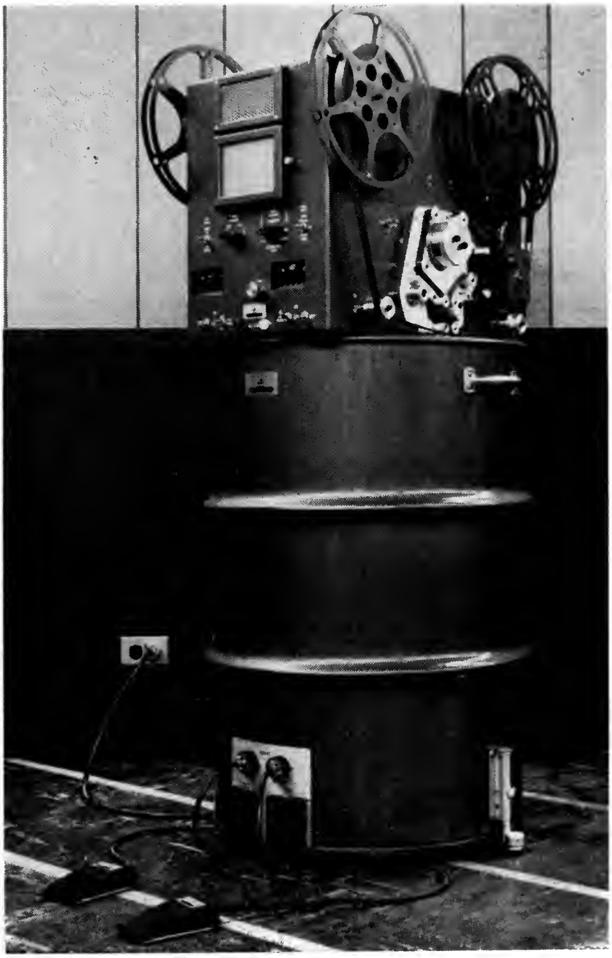


Fig. 1. Editor twin with sound side threaded and mounted on barrel pedestal with foot-treadle and touch-plate controls.

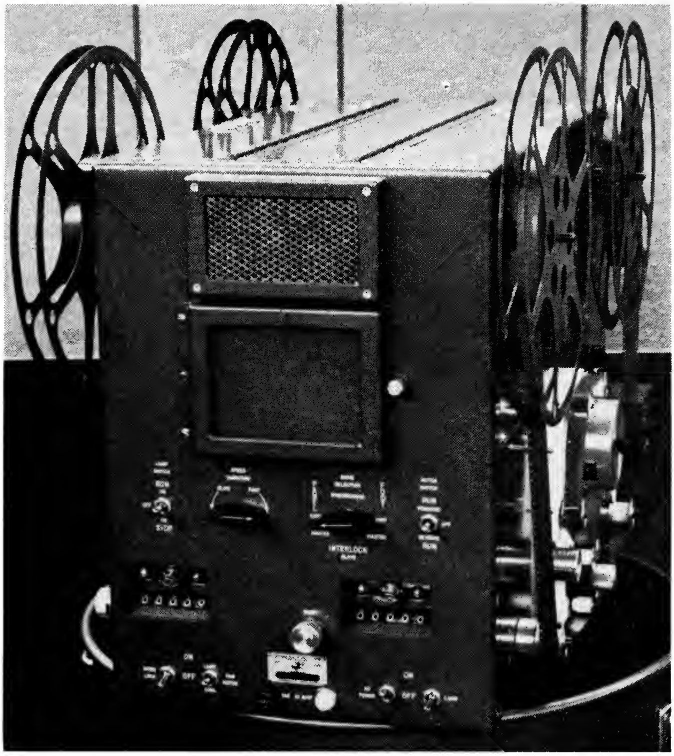


Fig. 2. Editor twin showing sound side threaded, footage counters, motor and lamp controls, screen and loudspeaker frames.

engineered to equal the performance of similar units in a studio equipment group. Film scratches, abrasions and perforation deformation are minimized by the wide use of fluoroethylene plastic in rollers and shoes, combined with a dependable, nonintermittent system of picture projection. A welded metal case houses all drive components and electronic equipment and encloses the picture-projection path. Operating controls are grouped on the front of the case which contains a rear-vision screen, loudspeaker and footage counters. The case sides serve as mounting walls for separate work-print and sound-track film transports complete with torque-motor driven reel spindles and cast assemblies for the alignment of sprockets, pad rollers, photographic and magnetic sound-scanning units and the picture-projection and imaging optical systems. Coupling knobs on each side select either or both transports, with permanently linked footage counters for record purposes. In addition, a compact assembly on the sound side facilitates aural magnetic-track editing.

Dynamic Scanning

Magnetic tracks are normally reproduced or scanned by running film at a uniform speed past a stationary magnetic head in contact with the magnetic coating. Track scanning is also feasible if the film is held stationary and the head moved while maintaining contact with the coating. This method is used in the editor dynascanner, which employs a magnetic head rotating within a film-wrapped drum and contacting the magnetic coating along a film length corresponding to from two to five spoken words. Twin guide rollers determine the drum wrap which is an integral part of the film path. Head rotation is controlled by a small synchronous drive motor operated by a switch on the control panel.

In operation, a magnetic track roll is threaded on the sound side and run against the work print with the scanner drum rotating and the head stationary. Word endings are located by stopping the machine, decoupling the sound side and powering the head drive motor. The drum is now stationary and the head rotates continuously, reproducing only the portion of the magnetic track which wraps the drum. A knob on the film sprocket is then turned slowly to position the exact word end at a point on the drum where the moving head leaves the coating. Engraved frame lines on the drum face assist the editor in marking the film for future cutting. Word beginnings are found and marked in the same manner.

Recording and Copying

The producer who cannot assume the risk of cutting an irreplaceable original magnetic sound track must re-record, or copy it. The copying process requires a magnetic reproducing or "dubbing" machine, an electronic audio-control channel, a magnetic recording machine and a monitor system. The producer usually rents the facilities of a sound-service studio and pays rental fees plus film costs for the copying service. If he uses the auxiliary sight-cutting track method he finds his track-cutting costs rising sharply above the standard photographic sound work-print costs which were part of his earlier budgets.

Should he decide to do his own magnetic-track copying and edit the copied track by dynamic-scanning methods without visual aids, he must have equipment which technically approaches the quality of units in the service studio. This equipment requisite, with one addition, is supplied by the basic editor twin, which has been designed to operate with a small, complementary console recording amplifier (Fig. 3), to perform a wide range of recording and re-recording operations.

Fig. 3. Mite recording amplifier showing control panel and input and output receptacles.

The console amplifier is housed in an aluminum case with detachable cover, with carrying handle and neck strap for transport. Power is supplied from dry batteries of the portable type but large enough for operation over an extended period. The amplifier gain is in excess of 100 db, and contains a high-frequency oscillator and mixer stage for direct cabling to a magnetic recording head. Output cable lengths up to 25 ft in length are practicable, as the bias voltage is read on the panel volume-indicator meter and is adjustable from a panel knob. Input impedances of 50, 250 and 500 ohm are available for low-impedance microphone use. A record-re-record switch on the panel is provided for microphone recordings or editor copying work. In the re-record position only the output stage and bias oscillator are powered. A second record-rehearse switch powers the oscillator for extended rehearsal periods, and also disconnects the volume indicator. Oscillator tank and coupling coils are of high Q, mounted in a shielded case containing tunable capacitors. Recordings cannot be made with the switch in the rehearsal position, and the operator is always certain recording is taking place when the volume indicator is operating. Batteries are accessible by removing a screw and folding back half of the amplifier control panel. Amplifier response is flat to 9000 cycles/sec and intermodulation products are less than 1%.

The case cover contains a crystal earwig monitor unit with cord and jack, microphone and output cables, microphone, desk stand and a tripod capable of elevating the microphone 7 ft above floor level. The tripod is also adaptable for use as a hand-held microphone extension pole 8 ft in length. The complete case is 10.5 in. long, 3 in. wide and 8.5 in. high, and weighs 10.25 lb.

There are many uses for a recording editor and console which do not demand personnel with engineering experience. The film editor employs the magnetic track for voice comments and advice to the producer at a rough work-print showing, to the composer who will write a score, or to the special-effects department for spotting wipes and dissolves. With even reasonable care it is a simple matter to record a narration track, and a variety of sound effects can be made, synchronized with work-print action, if desired. The console amplifier suffices for this work, and is suitable for basic stage-dialogue recording.

More complicated mixing consoles are necessary for involved procedures, as are additional sound reproducers. Matching sound twins are provided for this purpose, serving as additional editing heads in the cutting room and as multiple copying machines when 16mm magnetic-striped release prints are needed in quantity. Each machine is equipped with the synchronous-interlock variable-speed motor developed especially for the editor twin, insuring frame-for-frame synchronism between all machines without additional distributor or master control equipment. Any combination of 16mm, 17.5mm and 35mm tracks is possible for multireel editing and synchronizing.

When a sound twin is used in interlock with a twin editor many unusual combinations are available for projection, recording and re-recording. One of the most interesting from the standpoint of the film cutter and sound engineer is the possibility of "cutting" sound tracks electronically, without having recourse to the scissors or film splicer. An entire dialogue reel can be assembled by matching the opening picture scene with its associated photographic or magnetic sound track on the editor, followed by re-running and re-recording to a separate magnetic film on the sound twin, used as a recorder. Following picture scenes are cut and spliced as desired, then matched with sound tracks which are reproduced on the editor and recorded magnetically on the sound element. Previously recorded tracks are played back with previously cut and spliced picture scenes of the roll under assembly, and the following track is reproduced, recorded and monitored instantaneously when the rehearse-record switch on the control console is operated. In this manner original magnetic sound tracks can be preserved on the same film roll on which they were originally recorded.

Such a system is especially valuable for the assembly of sound tracks which have been recorded against picture loops in the well-known dubbing, or foreign-version scoring process. The illuminated footage counter with frame wheel is an accurate manual-switching reference, but sound sequences separated by five frames may be re-recorded automatically when a splice-actuated microswitch on the editor picture side is used. This switch controls a speech relay of the sequence type, which also stops the recording when the scene ends. All tracks are reproduced by the standard editor amplifiers, and the auxiliary recording console connects directly to the erase and record heads of the sound twin during recording.

Editor Amplifier

A fully equipped editor twin is furnished with separate photographic and magnetic scanning elements on the sound and picture sides. The head and photocell leads connect to inner case receptacles mating with connectors on the plug-in amplifier chassis. The chassis and amplifier control panel are combined in an assembly for case closure, with jacks, volume controls, switches and fuses appearing on the panel. Power and motor-control receptacles are divorced from the amplifier and mounted on the rear of the case above the amplifier panel. Four two-stage preamplifiers, each with low- and high-frequency compensating feedback loops, are used to amplify the output signal of the magnetic heads and photocells. Individual potentiometers control loudspeaker editing volume, or track levels during re-recording. Photocell volume controls are combined with exciter lamp switches; lamp currents are not changed when one or both lamps are used.

Closed circuit jacks on the panel connect the magnetic heads to the preamplifier inputs, so that either head may be cabled to the output of the recording console by a phone plug and cord. Separate 8-ohm, 500-ohm and headset jacks terminate the amplifier output. The 500-ohm circuit is used for re-recording with the console and for connection to the power amplifier and loudspeaker of monitor or review-room equipment. The 8-ohm jack normals to the speaker in the editor case and is used for external connection to a larger loudspeaker. Provision is made for the use of a headset when circumstances prohibit loudspeaker operation in a cutting room where several machines are active. The amplifier tube heaters as well as the exciter lamps are supplied with d-c from separate rectifier systems. The amplifier plate rectifier tube and filter components are on the chassis but the power transformers, selenium stacks and low-voltage filter components are remotely mounted in the editor case, connected to the amplifier through the mating receptacles. A neon pilot lamp on the panel lights to indicate failure of the amplifier fuse.

At the 2-w rated output, a signal-to-noise ratio in excess of 55 db is achieved, with intermodulation products of less than 1%. Amplifier gain is 105 db with a flat response from 30 to 10,000 cycles/sec. Output power is more than ample for operation of the case loudspeaker, and is sufficiently high to drive a remote speaker of larger size at sound levels associated with medium review rooms.

Lower-performance amplifiers are also furnished with integral power supplies.

Frequency response and distortion are similar but signal-to-noise ratio is limited to 35 to 40 db. Noise ratings include magnetic heads connected to the amplifier inputs.

Design Elements

The exciter lamp, sound optical system and magnetic head needed for photographic and magnetic track reproducing have been combined in a compact assembly with all requisite focusing and adjustment controls. The prefocused exciter-lamp mount includes a push button which relieves spring pressure for replacement. A slitless lens system has accurate azimuth adjusting screws, and the entire assembly is movable micrometrically for focus and track location. The emulsion planes of standard and nonstandard prints are selected quickly by a limited-throw angle lever.

A subassembly mounts the retractable magnetic head, with adjustments for azimuth, track location, tangent positioning and film-plane contact. The head is controlled by a detented selector knob on the assembly-casting cover. A single knurled screw fastens the cover, which is grilled for lamp ventilation.

In combination with a photoemissive cell on the film-transport assembly and the compensated preamplifier the photographic scanning system reproduces 16mm tracks with a range of 40 to 7000 cycles/sec without deviation. The magnetic scanning head and its associated preamplifier reproduce magnetic sound tracks faithfully over a range of 40 to 9500 cycles/sec. A complete photomagnetic scanner assembly is furnished on the sound and picture sides of a fully equipped editor twin.

Projection and Imaging Optics. A separate assembly houses the projection lamp, reflector, heat absorbing phosphate and aspheric-condenser lens for projection. The standard 100-w prefocused lamp may be replaced by 200- and 300-w lamps for large-screen wall projection. The aspheric-condenser element images the lamp filament in the aperture of the objective lens. Two first-surface mirrors in slab mountings reflect the illuminated film frame to a rear-vision daylight screen 5 × 7.5 in. A 90° rotation of the initial mirror reflects the picture at right angles to a wall screen. All glass parts are accessible for cleaning.

Nonintermittent Picture Projection. The continuous projection of a motion-picture frame sequence with a multifaceted prism has depended on the principle of control of prism rotation by the moving film, and has demanded gearing of extreme precision. The editor operates with a conventional twelve-sided prism, gear connected to two film-registering sprockets. A Gilmer pulley on the prism shaft is connected by a timing belt to a low-speed motor-driven pulley, and a combination aperture plate and pressure shoe produces tension in the film which cancels gear backlash. The film is side guided at the shoe to eliminate weave.

Drive Motor. For flexible operation, either alone or with other units, a single drive motor was developed for the editor by W. R. Turner. The motor runs synchronously at 1800 rpm, variably over a range of 0 to 3400 rpm and in synchronous interlock with the motors of other machines. Forward and reverse operation is controlled manually by a toggle switch on the front panel or by treadle switches or foot touch plates mounted in several types of pedestal bases.

Because of the positive nature of the interlock design all machines can be started, stopped and restarted without loss of synchronism. Machines of various types may thus be grouped for operation without dependence on coupling shafts, common bases or tables. The motor is powered from standard 110/115-v, 1-phase, 60-cycle mains, and is also supplied for 50-cycle use.

Decoupler Knobs and Footage Counters. The picture and sound sides may be run in mechanical lock or individually, by operation of the decoupler knobs. A slight pull out and 90° twist disconnects the film-transport sprocket shaft from the low-speed motor shaft, allowing the sprocket knob to be turned freely for film movement. Cove-mounted footage counters are permanently connected to the sprocket shafts of the sound and picture drives, operating independently of the decouplers. The counters have four digit wheels and a forty-frame wheel, and are illuminated.

Reel Spindles and Controls. The spindle torque motors are powered by the action of lift rollers on the case sides. After threading, the operator rotates the film reels manually to eliminate slack, raising the lift rollers. As the rollers lift, microswitches supply power to the spindle motors, maintaining the film to and from the sprockets under tension. When film runs out the falling lift rollers disconnect the motors and the reels come to rest. The lift rollers are also used for high-speed rewinding and winding under the control of a panel toggle switch. Each motor is cradled in a bracket for axial tilting against a balance spring. A weight increase of the reel due to added film lowers the motor position and actuates a microswitch on the bracket. Spindle torque is influenced by two capacitors, selected by the switch. The motors are not connected with the wiring of the drive motor, and do not operate when hand-held rolls are threaded. The spindles accept standard 400-, 800- and 1200-ft reels.

Pedestals. Hand-held rolls exit from the machine directly downward to eliminate lengthy guide chutes. Picture and track takes double wound on a single roll are easily fanned out and side threaded, dropping into twin cotton barrel liners in the base. The barrel bottom contains five single-ball antifriction casters for floor clearance, movement and rotation. A circular floor mat with double race rails may be used under the barrel for rapid center swiveling. Handles and foot-operated locking pads are standard equipment.

A metal-case pedestal matching the dimensions of the editor base is also supplied with a tilting top and formed rods for side cotton bags. Both bases are fitted with foot touch plates vertically mounted for start–stop and forward–reverse motor control. Receptacles paralleling the touch-plate switches are provided for connecting sloping foot treadles or hand-held pear-button switches. The base design accepts individual splicers on folding drop leaves for direct film cutting without removal to a splicing table.

Rollers and Shoes. The tetrafluoroethylene resin (Teflon) used in the construction of the rollers and shoes possesses several remarkable properties. It has high adhesive resistance, with a waxy surface on which nothing will stick. It is highly inert chemically. Machined in roller form it repels dirt particles that might scratch film emulsions. In shoe form it safely changes film direction without scoring or unusual deformation. It is nonflammable and has a service range of from minus 320 to plus 500 F. The Teflon rollers used are bushed with oilless bearings and have pressed anodized Duralumin side flanges.

The editor case design and picture-projection system permit the use of either side, or both, for picture-film transport and projection. By increasing the case width, two picture screens may be installed for the simultaneous projection of long shot and close-up camera takes. The production of films for television stresses the two-camera technique, and the editing of both films on a common machine with side-by-side pictures aids the cutting process. An interlocked sound twin is used for sound-track matching.

The double-side picture-projection system has also lessened the difficulty of editing and assembling three-dimensional 35mm films. A single screen is used with the projection throws superimposed, and the screen is viewed conventionally through polarized glasses or through an extension jib-mounted polarized septum viewer. An interlocked sound twin for three-track magnetic-track reproduction is supplied, with three loudspeakers in a composite wall baffle. The review of films with high aspect ratios requires only the correct aperture and the addition of any specified magnetic-head type with multiple amplifiers and speakers.

Magnetic sound tracks were once considered valuable only as a preproduction aid. Their eventual use on release prints, either 16mm or 35mm, was discounted because of the vast problem of equipment modification and replacement. It is now apparent that this problem may be solved in the very near future. Magnetic projectors for reproducing 16mm magnetic edge-striped prints are already in wide use. Multiple magnetic stripes on 35mm prints are featured by CinemaScope and similar systems and theaters are now being rapidly equipped to show these films. Cinerama has demonstrated the practicability of recording and playing back with six magnetic sound tracks in a system which has discarded photographic sound completely. Three-dimensional films have been released accompanied by separate magnetic sound rolls using three tracks which require a magnetic reproducing machine interlocked with a projector in the theater booth. A large number of theaters are now making such installations. Television networks depend upon an interlocked magnetic sound reproducer for kinescoped programming and will undoubtedly adopt the magnetic-striped release print at a later date.

Because of its adaptability to the many phases of picture and sound editing, sound recording, re-recording and magnetic-print production, the editor and its associated units would appear to merit the close study of motion-picture producers.

Acknowledgments

The author sincerely appreciates the assistance of G. J. Badgley, U.S. Naval Photographic Center, Dr. E. C. Fritts of the Eastman Kodak Co., and Dr. Franz Ehrenhaft of Scanoptic, Inc.

Discussion

George Lewin (Signal Corps Photographic Center): Could you clarify the function of the rotating head on the side? Is that for repeating a word for spotting purposes?

Mr. Hicks: We are stressing the importance of determining precisely the beginning and end of words. Visualizing devices such as modulation writing and combinations of magnetic stripes with photographic sound tracks do not always provide a definite indication of word endings visually, as most endings are low in level, high in frequency or a combination of both. These sounds are very difficult to see, and it is not unusual for the film editor to cut a track and lose an "ess" or a similar sound. He also often fails to see or hear low-level modulations which are a part of stage background sounds and leaves them in the track. These must then be further edited after they have been noticed during a rehearsal mixing session.

With the dynamic scanner the film stands still while the head is rotated. The head reproduces only the words or parts of words which wrap the scanner drum, and film on the drum can be shifted by the editor until the word beginning or end is heard. After the exact spot is determined the film is marked and cut in the usual way. The drum wrap allows from two to five words to be scanned, depending on the speed of the original speech. Scanning sound tracks in this manner helps the film editor considerably, especially when high-quality sound reproduction is combined with low machine noise.

Automatic Film Splicer

By A. V. JIROUCH

An automatic film splicer is described in which an accurate join is obtained rapidly by the movement of two levers. The essential requirements of a modern splicer and their practical fulfillment are discussed.

Perhaps because a splice is such a small thing very little attention has been given to the matter of splicing in the motion-picture industry. Improvements have been suggested from time to time in new patents and in the technical literature, but few have actually been put into effect. The result is that in spite of the vast progress made in the industry generally many of the same splicing problems that were experienced 45 years ago are still being encountered today. The work of the SMPE Subcommittee on 16mm Film Splices[1] may be considered as the first serious discussion of the problems in this field with practical suggestions for improvement.

Work was begun in 1945 to design a splicing machine which would cut, scrape and apply cement and appropriate pressure through a limited number of operations to ensure a perfect splice without dependence on the skill of the operator. The first prototype was an electrically driven machine.

Scraping. Different types of scraping tools, both static and rotating, were tested, the surface of each scrape was photographed and solubility tests made on different bases. During the progress of the work these tests gave good experience with different mixtures of practically all known solvents. Samples of the splices made were stored and later gave valuable information with respect to ageing of different types of film base and durability of joins.

As the number of samples increased it became more and more evident that the best results were achieved with tools removing the emulsion, substratum and skin of the base with one stroke, leaving the base rough, clean and open for penetration of solvents. It was not until six prototypes were built that it was possible to solve the question of uniform depth of scrape. This was achieved through a combination of specially shaped cutting tools, each one removing a part of the emulsion only (see Fig. 1 at E 41, 42).

To determine the optimum width of join about 2500 different samples were used to show that joins ranging from

---

Presented on October 7, 1952, at the Society's Convention at Washington, D.C., by A. V. Jirouch, Cine Television Equipment (Overseas) Ltd., 317 Belle Grove Rd., Welling, Kent, England (paper read by Harry Teitelbaum, Hollywood Film Co., 5446 Carlton Way, Hollywood 27, Calif.).
(This paper was received October 7, 1952, and in revised form March 16, 1953.)

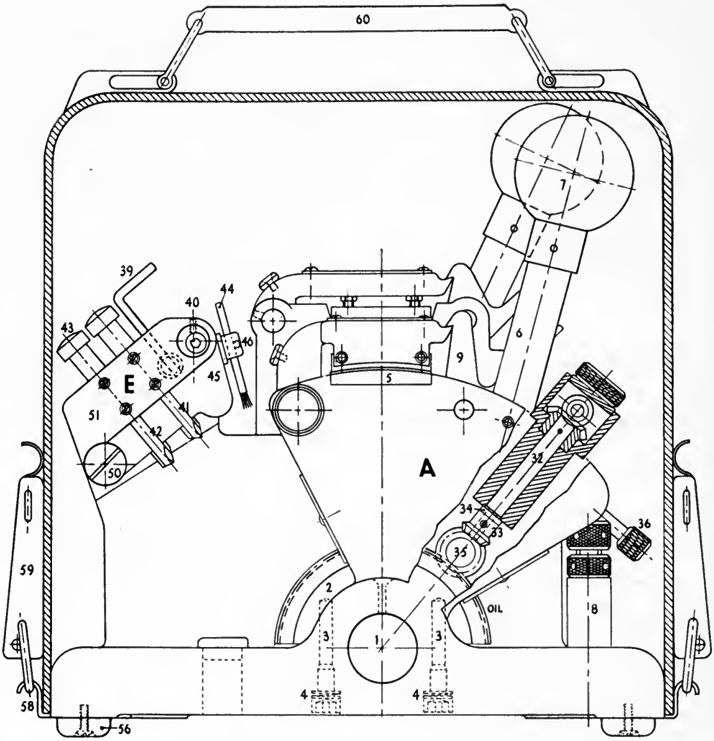


Figure 1

45 to 70 thousandths of an inch had the same tensile strength. It was not difficult to produce an overlap 20 thousandths of an inch wide with a tensile strength greater than that of the base itself. It is not proposed at this time to discuss the different standards and widths of overlap used at present, but further data will be published on the durability of joins of different widths of overlap after completion of full-scale tests.

The application of cement. Experience gained during the tests just mentioned showed that superior results were obtained when the cement was applied on the glossy surface of the base, instead of on the scraped area (see Fig. 3 at D, A 52, B 19).

It was found that even better results could be obtained by applying the cement with a roller applicator of special surface and tension (see Fig. 3 at 37, 38). The repeated passage of this roller across the surface of the film base not only applied the correct quantity of cement but also increased the penetration of solvents by agitation of the cement layer. In this way the base was dissolved to a sufficient depth to ensure a perfect weld. This principle of application has also solved the difficulty of anti-halo coating on several materials so that separate scraping of the coating is no longer required.

Controlled pressure. Throughout the years various improvements have been made, but pressure control has become more and more important. Much attention was therefore given to the

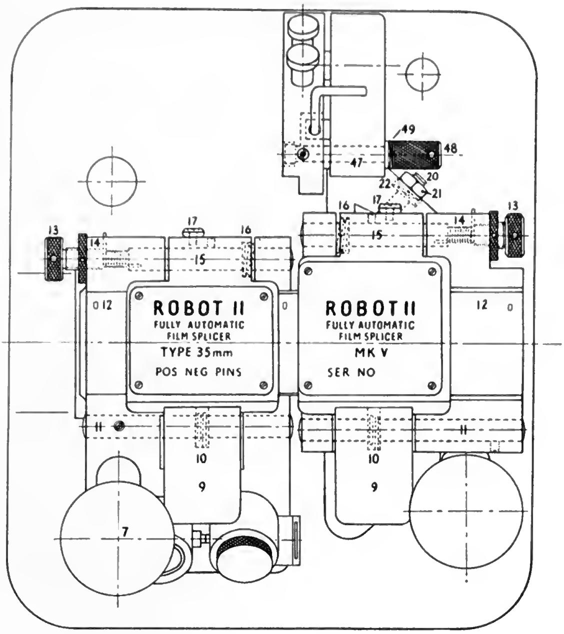


Figure 2

cam-locking mechanism and the diagram (see Fig. 3 at C 28, 53, etc.) shows that the actual pressure is applied at the moment when the cam is locked.

Suitable universal cement. The general use of safety base has introduced certain difficulties with regard to film cement. Cellulose acetate is a linear high polymer and displays the remarkable properties of a long-chain molecule, but the general solubility is somewhat more limited than that of cellulose nitrate. The fast mechanical operations of the machine permitted the use of low-viscosity solvents of balanced evaporation time. In this way no additional heating is required and the cement maintains its characteristics throughout the application and storage.

Tests were made to prove that evaporation of solvents and loss of plasticizers from the base do not affect the durability of a splice made with this cement in conjunction with the mechanical properties and speed of this machine. Several loops each with six joins were incubated by Kodak Limited, Harrow, England, and the effective ageing was observed by measuring the loss of solvents. All samples, even when prepared under different working conditions (room temperature and relative humidity), have shown greater tensile strength than the base itself. Seventeen of these samples were presented with the paper and it was found impossible to separate the splices by any means.

Details of operation. It is well known that a good scrape with poor application of cement, uneven pressure or an unsatisfactory quality of cement will never give a reliable splice. And, of course, a poor splice is obtained with any combination of these factors.

Recognizing the problems, all the above considerations were considered in designing the Robot Automatic Film Splicer which integrates the scraping,

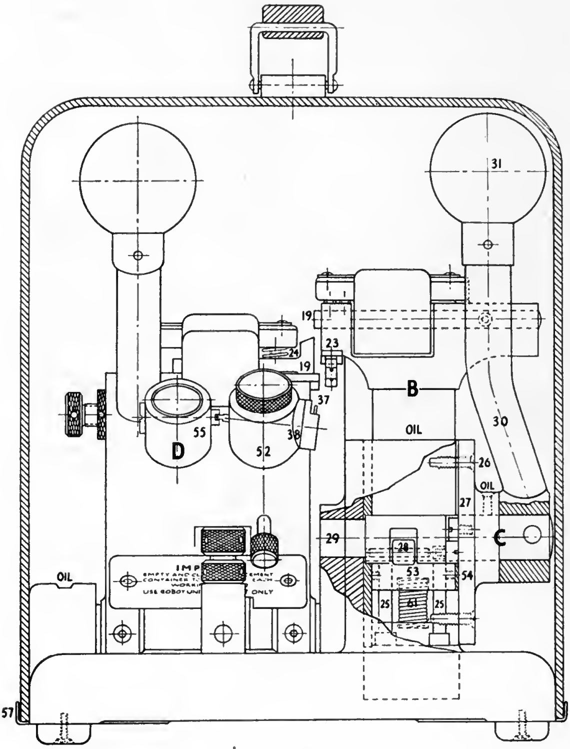


Figure 3

the application of cement and control of pressure, thereby providing the perfect splice on all types of film base presently in use. It is simple to operate and the influence of the human element is limited to the movement of the two levers only.

The forward and backward movement of the rocking block (Fig. 1 at A) scrapes the emulsion to uniform depth and at the same time applies cement to the opposite part of the film. The up-and-down movement of the right sliding block (Fig. 3 at B) cuts both ends of the film squarely and applies the pressure.

The machine is sturdily built, all important parts being made of stainless steel, ground and lapped, and both rocking and sliding movements are compensated for wear by spring-loaded tension (see Fig. 1 at A 1, A 2; Fig. 2 at 20, 21, 22). The three-point register pins allow both negative and positive film to be spliced without adjustment being required.

The cement tank holds sufficient cement for approximately 50 splices and a special adaptor can be fitted so that the machine can be operated all day without refilling.

The scraping tools of high-speed steel will never require replacement and seldom require sharpening. Machines in practical use for 36 months far exceeded the originally claimed 50,000 operations without resharpening.

The Robot II weighs 38 lb and is equipped with a metal dust-proof cover (see Fig. 1 at 58, 59, 60) and can be operated anywhere without being attached to the bench (see Fig. 1 at 61,

Fig. 4. The Robot II Splicer—Mark V 35mm model.

56). Its dimensions are $7\frac{1}{4} \times 8\frac{3}{4} \times 6\frac{1}{2}$ in.

Acknowledgment. The author would like to express his appreciation to Messrs. Kodak Limited, Harrow, England, for their cooperation and assistance in the preparation of samples.

References

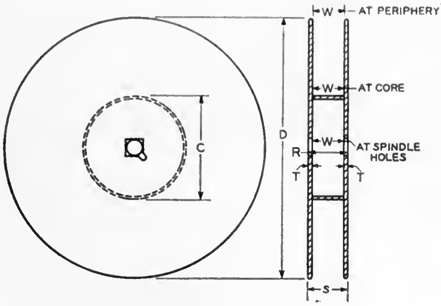
1. Report of the Subcommittee on 16mm Film Splices, *SMPE, 47:* 1–11, July 1946.
2. Pierre Jacquin, "Collures et colleuses," *La Technique Cinématographique,* Sept. 1948.

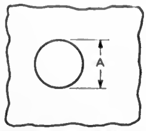
Revision — PH22.11 – 1953
16mm Motion Picture Projection Reels

This American Standard was republished in the September 1952 *Journal* on pp. 233–237. Dimension S was incorrectly designated as an inside dimension in the drawing on p. 1 of the Standard (*Journal* p. 234). The complete Standard has been processed as a revision and the full Standard, ASA's PH22.11-1953 (officially a revision of PH22.11-1952), is published on the following pages.

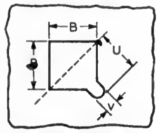
American Standard
for
16-Millimeter Motion Picture Projection Reels

ASA
Reg. U. S. Pat. Off.
PH22.11-1953
Revision of
Z22.11-1941
and
Z52.33-1945
*UDC 778.55





ENLARGED VIEW OF HOLE IN FLANGE ON LEFT IN SECTIONAL VIEW SHOWN ABOVE



ENLARGED VIEW OF HOLE IN FLANGE ON RIGHT IN SECTIONAL VIEW SHOWN ABOVE

Table 1

See page 3 for notes.

Dimension	Inches	Millimeters
A	0.319 +0.000 −0.003	8.10 +0.00 −0.08
B	0.319 +0.000 −0.003	8.10 +0.00 −0.08
R[1]	0.790 maximum	20.06 maximum
S[2] (including flared, rolled, or beveled edges, if any)	0.962 maximum	24.43 maximum
T (adjacent to spindle)	0.027 minimum 0.066 maximum	0.69 minimum 1.68 maximum
U	0.312 ±0.016	7.92 ±0.41
V	0.125 +0.005 −0.000	3.18 +0.13 −0.00
W, at periphery[3]	0.660 +0.045 −0.025	16.76 +1.14 −0.64
at core[4]	0.660 ±0.010	16.76 ±0.25
at spindle holes	0.660 ±0.015	16.76 ±0.38
Flange and core concentricity[5]	±0.031	±0.79

Approved September 11, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

American Standard

for

16-Millimeter Motion Picture Projection Reels

ASA Reg. U. S. Pat. Off.

PH22.11-1953

Table 2

Capacity	Dimension	Inches	Millimeters	Capacity	Dimension	Inches	Millimeters
200 feet[6] (61 meters)	D, nominal	5.000	127.00	1200 feet (366 meters)	D, nominal	12.250	311.15
	maximum	5.031	127.79		maximum	12.250	311.15
	minimum	5.000	127.00		minimum	12.125*	307.98*
	C, nominal	1.750	44.45		C, nominal	4.875	123.83
	maximum	2.000*	50.80*		maximum	4.875	123.83
	minimum	1.750	44.45		minimum	4.625*	117.48*
	Lateral runout,[7] maximum	0.057	1.45		Lateral runout,[7] maximum	0.140	3.56
400 feet[6] (122 meters)	D, nominal	7.000	177.80	1600 feet (488 meters)	D, nominal	13.750	349.25
	maximum	7.031	178.59		maximum	14.000*	355.60*
	minimum	7.000	177.80		minimum	13.750	349.25
	C, nominal	2.500	63.50		C, nominal	4.875	123.83
	maximum	2.500	63.50		maximum	4.875	123.83
	minimum	1.750*	44.45*		minimum	4.625*	117.48*
	Lateral runout,[7] maximum	0.080	2.03		Lateral runout,[7] maximum	0.160	4.06
800 feet (244 meters)	D, nominal	10.500	266.70	2000 feet (610 meters)	D, nominal	15.000	381.00
	maximum	10.531	267.49		maximum	15.031	381.79
	minimum	10.500	266.70		minimum	15.000	381.00
	C, nominal	4.875	123.83		C, nominal	4.625	117.48
	maximum	4.875	123.83		maximum	4.875	123.83
	minimum	4.500*	114.30*		minimum	4.625	117.48
	Lateral runout,[7] maximum	0.120	3.05		Lateral runout,[7] maximum	0.171	4.34

*When new reels are designed or when new tools are made for present reels, the cores and flanges should be made to conform, as closely as practicable, to the nominal values in the above table. It is hoped that in some future revision of this standard the asterisked values may be omitted.

Note 1: The outer surfaces of the flanges shall be flat out to a diameter of at least 1.250 inches.

Note 2: Rivets or other fastening members shall not extend beyond the outside surfaces of the flanges more than 1/32 inch (0.79 millimeter) and shall not extend beyond the over-all thickness indicated by dimension S.

Note 3: Except at embossings, rolled edges, and rounded corners, the limits shown here shall not be exceeded at the periphery of the flanges, nor at any other distance from the center of the reel.

Note 4: If spring fingers are used to engage the edges of the film, dimension W shall be measured between the fingers when they are pressed outward to the limit of their operating range.

Note 5: This concentricity is with respect to the center line of the hole for the spindles.

Note 6: This reel should not be used as a take-up reel on a sound projector unless there is special provision to keep the take-up tension within the desirable range of 1½ to 5 ounces.

Note 7: Lateral runout is the maximum excursion of any point on the flange from the intended plane of rotation of that point when the reel is rotated on an accurate, tightly fitted shaft.

Appendix

(This Appendix is not a part of the American Standard for 16-Millimeter Motion Picture Projection Reels, PH22.11-1952.)

Dimensions A and B were chosen to give sufficient clearance between the reels and the largest spindles normally used on 16-millimeter projectors. While some users prefer a square hole in both flanges for laboratory work, it is recommended that such reels be obtained on special order. If both flanges have square holes, and if the respective sides of the squares are parallel, the reel will not be suitable for use on some spindles. This is true if the spindle has a shoulder against which the outer flange is stopped for lateral positioning of the reel. But the objection does not apply if the two squares are oriented so that their respective sides are at an angle.

For regular projection, however, a reel with a round hole in one flange is generally preferred. With it the projectionist can tell at a glance whether or not the film needs rewinding. Furthermore, this type of reel helps the projectionist place the film correctly on the projector and thread it so that the picture is properly oriented with respect to rights and lefts.

The nominal value for W was chosen to provide proper lateral clearance for the film, which has a maximum width of 0.630 inch. Yet the channel is narrow enough so that the film cannot wander laterally too much as it is coiled; if the channel is too wide, it is likely to cause loose winding and excessively large rolls. The tolerances for W vary. At the core they are least because it is possible to control the distance fairly easily in that zone. At the holes for the spindles they are somewhat larger to allow for slight buckling of the flanges between the core and the holes. At the periphery the tolerances are still greater because it is difficult to maintain the distance with such accuracy.

Minimum and maximum values for T, the thickness of the flanges, were chosen to permit the use of various materials.

The opening in the corner of the square hole, to which dimensions U and V apply, is provided for the spindles of 35-millimeter rewinds, which are used in some laboratories.

D, the outside diameter of the flanges, was made as large as permitted by past practice in the design of projectors, containers for the reels, rewinds, and similar equipment. This was done so that the values of C could be made as great as possible. Then there is less variation, throughout the projection of a roll, in the tension to which the film is subjected by the take-up mechanism, especially if a constant-torque device is used. Thus it is necessary to keep the ratio of flange diameter to core diameter as small as possible, and also to eliminate as many small cores as possible. For the cores, rather widely separated limits (not intended to be manufacturing tolerances) are given in order to permit the use of current reels that are known to give satisfactory results.

74th Convention

The Society's 74th Convention was just one month away as this issue of the *Journal* went to press; and it is therefore a very real pleasure to report that the Papers Program for this five-day affair that begins on Monday, October 5th, did not suffer seriously from the unseasonable summer. Skip Athey, Program Chairman, made the grade. He just beat our publication deadline with an optimistic report on the success of papers procurement efforts. The titles so far assembled are in goodly number and, equally important, are closely tied to the more notable technical developments of recent months.

Skip assures all readers that the following list of topics is firm and you will see for yourself that this schedule of events is as meaty and well balanced as any. Those who have handled similar program assignments in the past, however, will agree with Skip and his hard working assistants — Bill Rivers, Joe Aiken, George Colburn, Gerry Graham, Charles Jantzen, Ralph Lovell, Glenn Matthews, Walt Tesch and John Waddell — that credit for the resulting program is hardly recompense for effort expended.

Stereophonic sound reproduction and the projection of wide-screen pictures will be lead-off topics for the opening technical sessions on Monday, October 5th. The afternoon will be devoted to "basic principles," and the following morning, Tuesday, October 6th, there will be a group of papers on new sound and projection equipment. In their commercial applications these processes represent the latest thing in motion pictures, so attendance at these sessions should be large. From present predictions it will include heavy representation from among American and foreign theater owners. Monday evening will be reserved for the presentation of awards.

This convention will have a session on high-speed photography, now set for Tuesday morning, to run concurrently with the session on new sound and projection equipment. The Tuesday afternoon session will be devoted to motion-picture laboratory equipment and practices, and the evening session will include two groups of companion papers; one, on production of foreign language versions of American motion pictures, and the other on the related technicalities of magnetic striping. This session will be held at the Signal Corps Pictorial Center.

To maintain a custom of long-standing there will be two paper sessions on Wednesday, October 7th, followed by a cocktail party and banquet. The subject of the morning session on Wednesday will be television, with papers having mostly to do with films for television broadcasting. In the afternoon papers and discussion will center around theater television. The cocktail party and banquet will be "informal" which somewhat illogically means "formal." In other words, if you have a dinner jacket, wear it; if you don't — well, do as you please, but by all means be comfortable and have a good time.

Thursday morning, October 8th will be "open" so breakfast may be had at lunch time. Thereby we will observe once again a tradition of old, long hallowed in the hearts of Wednesday revelers, but for several seasons now sorely breached out of deference to matters technical.

In the afternoon a general interest session will be held and on Thursday evening there will be an enlightening symposium on principles of 3-D.

The session on Friday morning, October 9th, will be devoted to the subject of new wide-screen techniques. Following the general session on Friday afternoon, Herbert Barnett will call for adjournment of the 74th Convention.

All convention paper titles and authors will be listed in the Advance Program that is scheduled for early first-class mailing to all members within and without the United States. A few items of particular interest taken from that list are these:

"A 35mm Stereo Cine Camera" by Chester E. Beachell of National Film Board of Canada

"Ferrite Core Heads for Magnetic Recording" by R. J. Youngquist and W. W. Wetzel of Minnesota Mining & Mfg. Co.

"Sensitometry of the Color Internegative Process" by C. R. Anderson, C. E. Osborne, F. A. Richey and W. L. Swift of Eastman Kodak Co.

"Stereoscopic Perceptions of Size, Shape, Distance and Direction" by D. L. MacAdam of Eastman Kodak Co.

"An Auxiliary Multitrack Magnetic Sound Reproducer" by C. C. Davis and H. A. Manley of Westrex Corp.

"A Film-Pulled Theater-Type Magnetic Sound Reproducer for Use With Multitrack Films" by J. D. Phyfe and C. E. Hittle of Radio Corporation of America

"A New Vidicon Tube for Film Pickup" by R. G. Newhauser of Radio Corporation of America

There is more to a convention than papers for which the chain of command includes Norwood Simmons, Editorial Vice-President, and Bill Rivers, Chairman of the Papers Committee. Jack Servies, Convention Vice-President is top manager of the many other convention matters including luncheon, banquet and the so-essential local arrangements. His work is always well delegated and for 74th Convention these are his assistants:

Local Arrangements
- Chairman — W. H. Offenhauser, Jr.
- Vice-Chairman — R. C. Holslag
- Vice-Chairman — S. L. Silverman

Registration — J. C. Naughton

Hospitality — Marie Douglass

Projection — Charles Muller

Public Address — George Costello and Dominick Lopez

Hotel & Transportation — L. E. Jones

Luncheon & Banquet — Emerson Yorke, J. B. McCullough and J. G. Stott

Membership — A. R. Gallo

Motion Pictures — V. J. Gilcher

Publicity — Harold Desfor and Leonard Bidwell

Current Literature

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

vol. 34, July 1953

Single-film, Single-projector 3-D (p. 319) *N. Cohen*

3-D Television (p. 320)

Vistarama — Wide-Screen System for 16mm Movies (p. 326) *H. A. Lightman*

Bell System Technical Journal

vol. 32, July 1953

Television Terminals (p. 915) *J. W. Rieke and R. S. Graham*

Electronics

vol. 26, Aug. 1953

Standards Converter for International TV (p. 144) *A. V. Lord*

Design of Export Television Receivers (p. 174) *G. D. Hulst*

Focus

vol. 38, no. 13, June 27, 1953

De Nieuwe Philips Televisie-camera (p. 267)

Ideal Kinema (Supplement to Kinematograph Weekly)

vol. 19, July 9, 1953

Carbons to Light the Wide Screen (p. 5) *R. H. Cricks*

The Equipment Behind CinemaScope (p. 9)

The Mathematics of Wide Screen (p. 17)

Proceedings of the I.R.E.

vol. 41, July 1953

Colorimetry in Color Television (p. 838) *F. J. Bingley*

The PDF Chromatron — A Single or Multi-Gun Tri-Color Cathode-Ray Tube (p. 851) *R. Dressler*

vol. 41, Aug. 1953

A Subjective Study of Color Synchronization Performance (p. 979) *M. I. Burgett, Jr.*

International Photographer

vol. 25, Aug. 1953

Editing 3-D (p. 5) *R. Fehr*

Processing Color Film, Pt. 2 (p. 22) *G. Ashton*

Graphic Representation of Various 3-D and Wide Screen Processes (p. 23)

International Projectionist

vol. 28, July 1953

Round-Up of the Wide-Screen Process (p. 5)

Visibility Factors in Projection, Pt. 3 — Color and Nature of Projection Light (p. 11) *R. A. Mitchell*

Projector Carbons for New Motion Picture Systems (p. 14) *F. P. Holloway, R. M. Bushong and W. W. Lozier*

Kino-Technik

vol. 7, July 1953

Der heutige Stand der Filmwissenschaft in Deutschland (p. 184) *E. Feldmann*

Raumfilm — mit Farbe Wirklichkeitsnah (p. 186) *H. N. O'Leary*

Möglichkeiten und Grenze der Farbkorrektur (p. 188) *A. Kocks*

Störungen bei der Vorführung von Tonfilmen (p. 193) *H. Tümmel*

Die Möglichkeiten zur Vertonung von Amateurfilmen (p. 194) *F. Frese*

Cameflex-Fernsehkamera Modell "T" 16mm (p. 198)

Motion Picture Herald (Better Theatres Section)

vol. 191, July 4, 1953

Crisis in Sound, 1953 (p. 11)

Precision Requirements of 3-D: Shutter Synchronization, Interlocking and Alignment (p. 15) *G. Gagliardi*

vol. 191, Aug. 1, 1953

Projection Factors of Wide-Screen Installation (p. 8) *G. Gagliardi*

New Carbons for the New Projection System (p. 31) *F. P. Holloway, R. M. Bushong and W. W. Lozier*

Radio & Television News

vol. 50, no. 2, Aug. 1953

Film for TV (p. 35) *H. J. Seitz*

Troubleshooting TV High-voltage Supplies (p. 48) *M. H. Lowe*

Know Your 1953 Emerson TV Receivers (p. 52) *B. Kutny*

R & TV News (Radio-Electronic Eng. Sec.)

vol. 50, no. 2, Aug. 1953

Pressure Testing of TV Tubes (p. 8) *G. D. Ostrander*

RCA Review

vol. 14, June 1953

Optimum Utilization of the Radio Frequency Channel for Color Television (p. 133) *R. D. Kell and A. C. Schroeder*

Principles and Development of Color Television Systems (p. 144) *G. H. Brown and D. G. C. Luck*

Color Television Signal Receiver Demodulators (p. 205) *D. H. Pritchard and R. N. Rhodes*

Colorimetric Analysis of RCA Color Television System (p. 227) *D. W. Epstein*

TV & Radio Engineering

vol. 23, no. 3, June-July 1953

Microwave Units for TV Services (p. 14) *S. Topal and W. T. Beers*

16-mm Projector for Television (p. 17)

Color TV Experimental Equipment (p. 19)

Low Cost TV Camera (p. 28)

Book Reviews

Photoelectric Tubes

By A. Sommer. Published (late 1952) by John Wiley & Sons, 440 Fourth Ave., New York 16. 118 pp. 27 diagrams. 4 × 6½ in. $1.90.

It would seem improbable that this little volume could treat the emissive type of photocell from the basis for the photoelectric effect in Einstein's and Fermi's theories, through physical aspects, chemical nature of complex cathodes, manufacturing techniques, spectral response and engineering application. Yet it does, and clearly.

The chapter headings give further clues as to what is to be found in the book: I, Historical Introduction; II, Theories of Photoelectric Emission; III, Photoelectric Cathodes; IV, Matching of Light Sources and Photocathodes; V, Vacuum Photocells; VI, Gasfilled Photocells; VII, Multiplier Photocells; and VIII, Applications of Photocells.

Material is included on the direct applications to sound motion pictures and television, which serves to relate all other material to the chief interest of the readers of this *Journal*.

Dr. Sommer is of the EMI Research Laboratories in England, but it appears that the British electrons behave exactly the same as do the American ones. Furthermore, American tubes are discussed. A convenient table of photocathode types for a dozen tubes and a bibliography of 69 entries to the scientific and engineering literature of both the United States and Europe are included.—*Harry R. Lubcke*, Registered Patent Agent, 2443 Creston Way, Hollywood 28, Calif.

Photography, Its Materials and Processes, 5th ed.

By C. B. Neblette and 14 collaborators. Published (1952) by C. Van Nostrand, 250 Fourth Ave., New York 3. vii + 490 pp. + 10 pp. index. 350 illus. 7 × 9½ in. $10.00.

Ed. Note: We have been unable to get a review long ago promised for the *Journal*. Rather than let this book go unnoticed, we have obtained permission to reprint the following review by Dr. O. W. Richards, American Optical Co., Stamford, Conn., from the *Journal of the Biological Photographic Assn., 20:* 121, Aug. 1952.

For twenty-five years this has been a standard book for photographers. Now it is encyclopedic and much of it has been written by experts including our Lloyd Varden. This volume of 33 chapters is primarily on materials and their use, shows the increasing technical progress in the field. Gone are chapters on enlarging and lantern slide making. Instead the emphasis is now on color. With the exception of a few chapters (including Varden's) the rest of the book is made from reference material up to about 1945 or 1947, so that some of it is already out of date. The section on electronic flash, for example, does not mention the new smaller tubes and the convenient voltage doubler circuits. For a student textbook, that it still states that it is, a chapter on the essentials of a good picture would add to the usefulness of the book. While it will probably be rather difficult reading for the beginner, the advanced photographer will find most of his questions answered and no department should be without this remarkably complete reference book.—*O.W.R.*

Television Scripts for Staging and Study

By Rudy Bretz and Edward Stasheff. Published (1953) by A. A. Wyn, 23 W. 47 St., New York 36. 328 pp. + 4 pp. index. Numerous illus. $4.95.

An earlier book, *The Television Program* by the same authors, was reviewed for this *Journal* with the conclusion that it did all that a book could do for those learning television production. The earlier reviewer emphasized the values of actual experience and observation. These authors are aware of those values for they have extensive experience teaching where complete equipment was a part of the school. They are both still teaching, between or along with other stints. And while their first book goes on being adopted as the text in additional dozens of schools and universities, this book comes as an additional tool for the teacher and student director or producer.

Considering that, in this *Journal's* modest fan mail, the commonest specific reference has been to articles by Author Bretz, we need not here attempt to assess in any detail the parts of this book. Introductory to the second and third parts of the book, which are "The Simpler Formats" and "Full-Length Scripts," is the friend-of-the-engineer part, "Creative Camera Techniques" which includes chapters on pictorial composition (control over subject) and shots in sequence (cutting techniques). We suggest that student and learning directors who become aware of what can and cannot be done with their studio facilities are important contributors to a well-engineered picture on the air.—*V.A.*

Technical Reporting

By Joseph N. Ulman, Jr. Published (1952) by Henry Holt, 383 Madison Ave., New York 17. i-xiv + 284 pp. + 5 pp. index. $4.75.

This is a good book for the many who need such a book. We are in favor of all such books, just as all busy editors are against the crimes which writers attempt against the general welfare of the readers.

Technical Reporting is shorter than many books telling engineers how to write because the author has followed his own advice: "You owe it to your reader to make your meaning immediately clear with a minimum of study on his part."

The author does not have the futile ambition to make grammarians out of technical men. He has prepared a text which is worthy of study and recurrent browsing and is useful in a modest way as a reference. He lists other books which serve standard reference purposes. This is not an officious apologia for a volume of fine points. It is an efficient presentation of common-sense bases for effective technical writing. The Table of Contents is a pleasure to read and use for it is fully but not ponderously supported by the text.—*V.A.*

Television Factbook, No. 17 July 15, 1953

Published (July 15, 1953) by Radio News Bureau, Wyatt Bldg., Washington 5, D.C. 356 pp. incl. folding wall map in color. 8½ × 11 in. $3.00.

The new 1953 midyear edition of this vast compendium of facts about the television world has a number of new departments, including sets-in-use by states and counties (both NBC Research's TV-&-radio count and CBS's TV count); the J. Walter Thompson Co. study of households and TV sets in "First 312 Markets of the U.S."; directory of TV stations in foreign countries; tables showing annual volume of advertising in U.S. by media, 1946–52; tabulation of financial data on leading TV-radio manufacturers; and first detailed listings of tuner, converter and receiving antenna manufacturers.

The *Factbook* provides personnel listings, facilities and ownership data and rate card digests of all TV networks (including the new Canadian), and of the 227 U.S. stations now operating or due to be in operation by August 1, and tabulations of new-station applications pending and outstanding construction permits.

Among other features are directories of program sources, FCC personnel, attorneys, engineers, consultants, trade associations, unions, publications, etc.; listings of community antenna systems, theaters equipped for TV, and directories of manufacturers of receivers, tubes, transmitters, studio equipment, etc.; channel allocation tables; FCC priority lists; network TV-radio billings, 1949–53; and FCC reports on revenues, expenses and earnings of TV networks and stations, 1946–52.

American Cinematographer Hand Book and Reference Guide

By Jackson J. Rose. Published (1953) by American Cinematographer Hand Book, 458 So. Doheny Dr., Beverly Hills, Calif. 8th ed., 328 pp., incl. advts. 4 × 6½ in. Flexible binding. Price $5.00.

The Eighth Edition of this standard reference guide has the charts, tabulations, formulas and indexes with which users of previous editions will be familiar. This edition has been announced as also covering these new features: Cinerama, television photography, zoom lenses, latensification, underwater photography, background projection, T-stops, Ansco Color Negative-Positive Process, Eastman Color Negative and Print Film, Du Pont Color Release Positive Film and many new charts and tables.

Workers in motion-picture and still photography and in television will find this still a very useful reference as last described when the seventh edition was reviewed in September 1950 in the *Journal.* — *V.A.*

"Research Film"

The Research Film Committee of the International Scientific Film Association announces a new bulletin, *Research Film*, designed as a vehicle for the international exchange of information in the field of its title. The tri-lingual publication is under the editorship of Dr. G. Wolf of Göttingen and Jean Dragesco of Paris. Notices appear in French, German and English; articles are published in their original language. Reports on American work are sought. Further information can be obtained from the chairman of the Research Film Committee, Dr. G. Wolf, Institut für Film und Bild — Abt. Hochschule und Forschung, Bunsenstrasse 10, Gottingen, Germany.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal.*

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 MEMBERSHIP DIRECTORY.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Austin, Otto, Motion-Picture Producer, Austin Productions, Inc., 232½ North Main St., Lima, Ohio. (A)

Ayling, Russell J., Electrical Engineer, Strong Electric Corp., 87 City Park Ave., Toledo, Ohio. (M)

Bass, Vincent F., Cinematographer, Photographer. **Mail:** 564 Rutland Ave., San Jose 28, Calif. (A)

Becker, Sherwin H., Editor, Douglas Productions. **Mail:** 5214½ South Drexel Blvd., Chicago 15, Ill. (A)

Berliner, Oliver, Audio-Video Consulting, Oberline, Ltd., 6411 Hollywood Blvd., Hollywood 28, Calif. (A)

Bogardus, John O., Motion-Picture Projectionist, W. S. Butterfield Theatres, Inc. **Mail:** 344 Coldbrook, N.E., Grand Rapids 5, Mich. (M)

Carlson, George, Television Supervisor, KSTP-TV, Inc., St. Paul, Minn. (M)

Constable, James M., Producer-Director, Wilding Picture Productions, Inc., 1345 Argyle St., Chicago, Ill. (M)

Di Lonardo, Hugh, Motion-Picture and Television Films Instructor, Television Workshop. **Mail:** 75 W. 97 St., New York, N.Y. (A)

Druz, Walter S., Research Engineer, Zenith Radio Corp. **Mail:** 228 South Center St., Bensenville, Ill. (M)

Dyer, Robert W., Studio Manager, Motion Picture Advertising Service Co., Inc., 1032 Carondelet St., New Orleans, La. (M)

Gaines, Albert, Motion-Picture Laboratory Technician, DeLuxe Laboratories. **Mail:** c/o Greenwald, 3210 Perry Ave., Bronx, N.Y. (A)

Grodin, Burton, President, University Camera Exchange. **Mail:** 3678 Crest Rd., Wantagh, Long Island, N.Y. (M)

Herrick, Kenneth P., Field Engineer, Radio Corporation of America. **Mail:** 2516 Fulton St., Toledo, Ohio. (A)

Hughes, Tom F., Motion-Picture Production Supervisor, American Airlines, Inc. **Mail:** 44 Shadyside Ave., Port Washington, N.Y. (A)

Imus, Henry O., Color Camera Technician, Technicolor Motion Picture Corp. **Mail:** 3180 Vista Del Mar, Glendale 8, Calif. (A)

Jarrett, A. W., Motion-Picture Cameraman, KOB-TV. **Mail:** 1934 Meadow View Rd., Albuquerque 1, N.M. (A)

Jensen, Peter Axel, Research Trainee, Technicolor Motion Picture Corp., Box 16–547, Hollywood 38, Calif. (A)

Keilhack, Francis W., Representative and Technical Adviser, Drive-In Theatre Manufacturing Co., 505 W. Ninth St., Kansas City, Mo. (M)

Koerner, Allan M., Eastman Kodak Co., Kodak Park, Bldg. 65, Rochester, N.Y. (A)

Krtous, George F., Engineer, De Vry Corp. **Mail:** 2547 South Harding Ave., Chicago 23, Ill. (M)

Laby, Lawrence M., Production Manager, Natural Vision Theatre Equipment Corp. **Mail:** 5461 Tampa Ave., Tarzana, Calif. (A)

Langendorf, Matthew P., Engineer, Ampro Corp. **Mail:** 3512 West Lemoyne St., Chicago 51, Ill. (M)

Lester, F. C., Broadcast Engineer, Mid-Continent Broadcasting Co., KOWH. **Mail:** 3514 N. 61 St., Omaha, Nebr. (A)

Lovell, Herman J., Chief Engineer, WKY Radiophone Co., 500 East Britton Rd., Oklahoma City, Okla. (M)

Lucas, James W., Aircraft and Mechanical Engineer, The Stephen-Douglas Co. **Mail:** 311 South Amalfi Dr., Santa Monica, Calif. (A)

Mavrides, William, Film Editor and Film Librarian, WAKR-TV, First National Tower, Akron, Ohio. (A)

Merrifield, Robert C., Television Set Lighting Technician. KLAC-TV. **Mail:** 220 South Hoover St., Los Angeles 4, Calif. (A)

Mirarchi, Michael R., Photographic Technician, Signal Corps Engineering Laboratories. **Mail:** 141 Atlantic Ave., Long Branch, N.J. (A)

Navarro, Jose C., Cinematographer, Television Technical Director, DZAQ-TV. **Mail:** 1230 Oroguieta, Sta. Cruz, Manila, Philippines. (A)

Newman, Robert P., Film Executive, Telepix Corp., 1515 North Western Ave., Hollywood, Calif. (M)

Reid, Seerley, Chief, Visual Education Service, U.S. Office of Education, Washington 25, D.C. (A)

Reynolds, Ernest M., Motion-Picture and Slide-Film Producer. **Mail:** 165 E. 191 St., Cleveland 19, Ohio. (M)

Richartz, Paul, Design Engineer, Bell & Howell Co. **Mail:** 87 Orchid Rd., Levittown, Long Island, N.Y. (M)

Richter, A. A., Service Engineer, Army and Air Force Motion Picture Service. **Mail:** 4927 Imlay Ave., Culver City, Calif. **(A)**

Rolph, Donald B., Motion-Picture Sound Recording. **Mail:** 15450 Pepper La., Los Gatos, Calif. **(A)**

Schley, Norman E., Cameraman, Director, Picturelogue, Inc., 204 Wisconsin Ave., Waukesha, Wis. **(M)**

Sherburne, Edward G., Jr., Navy Special Devices Center. **Mail:** 10 Clent Rd., Great Neck, N.Y. **(M)**

Stadig, Sidney V., TV Technical Supervisor, Westinghouse Radio Stations, Inc. **Mail:** 86 Spring St., Lexington, Mass. **(M)**

Walls, Fred M., Sound Engineer. **Mail:** 827 Wayne, Topeka, Kan. **(M)**

Washick, Walter J., Design Draftsman, Technicolor Motion Picture Corp. **Mail:** 1931 Lietz Ave., Burbank, Calif. **(A)**

Wilson, Jimmy, Producer and Photographer, Jimmy Wilson Studios, 724 S. 29 St., Birmingham, Ala. **(M)**

Winter, A. Roane, Assistant Sound Engineer, Missions Visualized, Inc. **Mail:** 1034 East Walnut Ave., Burbank, Calif. **(A)**

Wohler, Johann F., Optical Engineer, A. G. Optical Co., 5574 Northwest Highway, Chicago, Ill. **(M)**

CHANGES IN GRADE

Clarke, Anthony, **(S)** to **(A)**

Fullerton, Richard D., (A) to **(M)**

Tinker, Clarence J., (A) to **(M)**

Chemical Corner

Edited by Irving M. Ewig for the Society's Laboratory Practice Committee. Suggestions should be sent to Society headquarters marked for the attention of Mr. Ewig. Neither the Society nor the Editor assumes any responsibility for the validity of the statements contained in this column. They are intended as suggestions for further investigation by interested persons.

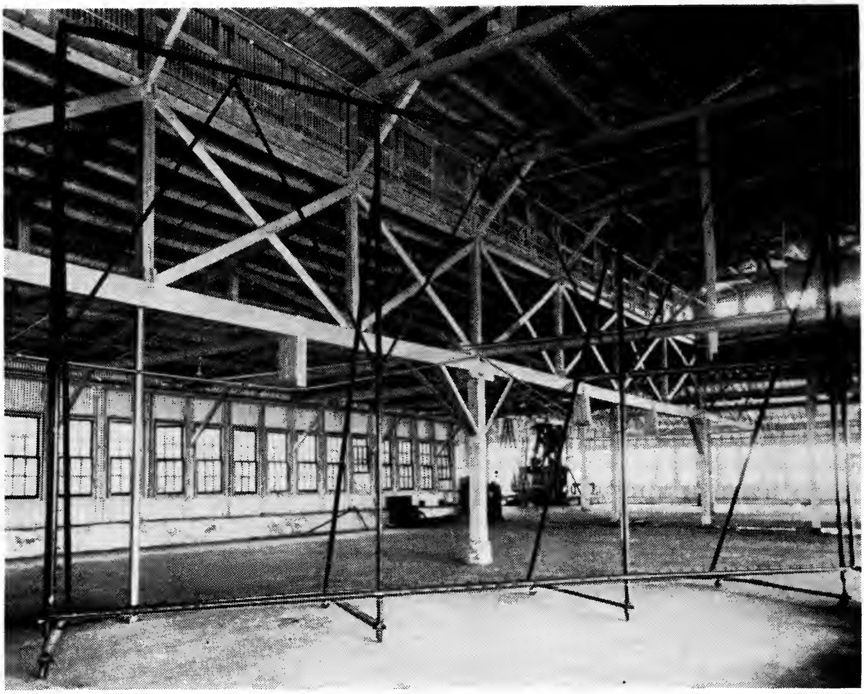
Saving Shipping Costs The laboratory plagued by high chemical shipping costs ought to consider the substitution of sodium thiosulfate-anhydrous for the crystalline hypo which contains 35% water. The ultimate cost of hypo can be determined on the basis that 65 lb of the anhydrous variety is equal to 100 lb of the common crystalline type. The use of anhydrous sodium carbonate (soda ash) can be substituted effectively for sodium carbonate-monohydrate on 85:100 lb basis. Also soda ash is stocked at various shipping fronts throughout the country.

A Universal Adhesive A new adhesive that may prove of interest to the motion-picture and television industries can be used to adhere felt, cork, sponge, solid rubber, etc., to a variety of surfaces. The manufacturer, The Rubber Latex Co. of America, 110 Delawanna Ave., Clifton, N.J., claims that their adhesive is the most universal one developed in recent years. The product, designated Rula 181–3, can be applied to rolls or sheets like paint and allowed to dry. Parts cut from the coated rolls or sheets can be shipped or laid aside, and upon being remoistened with a petroleum-type solvent or cleaning fluid, may be pressed into place on any surface such as steel, wood, paint, plaster, paper, glass, ceramics, etc., and become permanently adhered after an extremely short drying period. The adhesive may also be used in the conventional manner by applying and using while still wet.

This May Be a Good Film Cement A cement which has exceptionally good adhesive properties for cellulose acetate is called C D Cement #150. It is colorless, fast-acting and produces an unusually strong bond. This product may have possibilities as a good film cement and anyone interested should consult the manufacturer, The Chemical Development Corp., Danvers, Mass.

New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.



The Bowline Screen Frame is made of steel tubing, reportedly can be installed in less than an hour without special skills, and weighs about a pound for each square foot of screen surface — for a 20 × 30 ft screen, about 600 lb. The frame's adjustability is described: height, adjustable so that any aspect ratio can be obtained; tilt, degree of tilt easily set; curve, with radius laid off on the floor, the frame is set directly over the position line and formed. Both the tilt and the curvature can be varied or the frame can be adjusted to provide a flat screen. It is manufactured by H. R. Mitchell and Co., Hartsell, Ala.

SMPTE Lapel Pins

The Society has available for mailing its gold and blue enamel lapel pin, with a screw back. The pin is a ½-in. reproduction of the Society symbol — the film, sprocket and television tube — which appears on the *Journal* cover. The price of the pin is $4.00, including Federal Tax; in New York City, add 3% sales tax.

The Spectra Color Densitometer, manufactured by Photo Research Corp., 127 West Alameda Ave., Burbank, Calif., measures black-and-white (both print and visual), color and sound track by infrared phototube. The left head is used for black-and-white and color; the right head for sound track. A special interference filter can be used to limit the sensitivity to a narrow band at the peak region of infrared sensitivity. Separate zero adjustments for the blue, green and red color positions permit readings to be taken of a given patch without moving the film. The left head is always ready for black-and-white and color readings and the right head for sound-track readings. Change from one to the other is made by a switch. Both heads have special illuminated disks surrounding the apertures to facilitate finding desired areas.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, and there is no charge to the member.

Positions Wanted

Experienced motion-picture production man desires connection with film company as producer-director or production manager. During past 12 yrs. experience includes directing, photographing, editing, recording and processing half-million feet finished film, including educational films, industrials, TV spots, package shows for TV and experimental films. University graduate, married, twenty-nine years old; good references. Locate anywhere continental U.S. Write Victor Duncan, 8715 Rexford Drive, Dallas 9, Tex.

Film Production/Use: Experienced in writing, directing, editing, photography; currently in charge of public relations, sales and training film production for industrial organization. Solid film and TV background, capable administrator, creative ability, degree. References and résumé upon request. Write FPF, Room 704, 342 Madison Ave.. New York 17, N.Y.

Position Available

Wanted: Optical Engineer for permanent position with manufacturer of a wide variety of optics including camera objectives, projector, microscope and telescope optics, etc. Position involves design, development and production engineering. Send résumé of training and experience to Simpson Optical Mfg. Co., 3200 W. Carroll Ave., Chicago 24, Ill.

Department of Defense Symposium on Magnetic Recording

A full and worth-while program has been arranged to be held on October 12 and 13 in the Department of Interior Auditorium, Washington, D.C. The organizers plan to avoid a rehash of basic theory and intend the symposium to be a meeting ground where different branches of the magnetic recording industry may exchange views for their general benefit, as well as for the benefit of the Department of Defense. Individuals from industry engaged in magnetic recording development are invited to attend. There is no fee for registration.

E. W. D'Arcy will give a paper on "Calibrated Recordings and Measurement Techniques," reviewing the Society's position as reflected by progress on the subcommittee which he heads; and John G. Frayne is scheduled to present a paper on "Components and Mechanical Considerations."

SMPTE representative for the Armed Forces Symposium has been Joseph E. Aiken, Naval Photographic Center, Anacostia, D.C.

Meetings

The Royal Photographic Society's Centenary, International Conference on the Science and Applications of Photography, Sept. 19–25, London, England

National Electronics Conference, 9th Annual Conference, Sept. 28–30, Hotel Sherman, Chicago

74th Semiannual Convention of the SMPTE, Oct. 5–9, Hotel Statler, New York

Audio Engineering Society, Fifth Annual Convention, Oct. 14–17, Hotel New Yorker, New York, N.Y.

Society of Motion Picture and Television Engineers, Central Section Meeting, Oct. 15 (tentative), Chicago, Ill.

Theatre Equipment and Supply Manufacturers' Association Convention (in conjunction with Theatre Equipment Dealers' Association and Theatre Owners of America), Oct. 31–Nov. 4, Conrad Hilton Hotel, Chicago, Ill.

Theatre Owners of America, Annual Convention and Trade Show, Nov. 1–5, Chicago, Ill.

National Electrical Manufacturers Association, Nov. 9–12, Haddon Hall Hotel, Atlantic City, N.J.

Society of Motion Picture and Television Engineers, Central Section Meeting, Nov. 12 (tentative), Chicago Ill.

The American Society of Mechanical Engineers, Annual Meeting, Nov. 29–Dec. 4, Statler Hotel, N.Y.

Society of Motion Picture and Television Engineers, Central Section Meeting, Dec. 10 (tentative), Chicago, Ill.

American Institute of Electrical Engineers, Winter General Meeting, Jan. 18–22, 1954, New York

National Electrical Manufacturers Assn., Mar. 8–11, 1954, Edgewater Beach Hotel, Chicago, Ill.

Radio Engineering Show and I.R.E. National Convention, Mar. 22–25, 1954, Hotel Waldorf Astoria, New York

Optical Society of America, Mar. 25–27, 1954, New York

75th Semiannual Convention of the SMPTE, May 3–7, 1954, Hotel Statler, Washington

Acoustical Society of America, June 22–26, 1954, Hotel Statler, New York

76th Semiannual Convention of the SMPTE, Oct. 18–22, 1954 (next year), Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955, Drake Hotel, Chicago

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955, Lake Placid Club, Essex County, N.Y.

Increasing the Efficiency of Television Station Film Operation

By R. A. ISBERG

Techniques have been developed in the scheduling of film programs and the splicing of films which reduce the technical manpower required for operations. By utilizing oversize reels and remote control of the projection equipment, two men can easily handle audio and video control and also be responsible for normally unattended film projection equipment. Practical techniques of film splicing and editing are also described.

More than half of the average television station's program time is generally supplied by 16mm film. Film is required from sign-on to sign-off time which covers a period of from ten to seventeen hours per day. During major portions of the program schedule the entire operation usually depends upon film with no live studio participation. In some of the smaller stations the entire program schedule is transmitted from film and network microwave, if available.

From the standpoint of economy, it is desirable to have the studio, offices and transmitter at one location, but in many areas propagation considerations require that the transmitter be located on a high hill or mountain. This almost invariably results in separate studio and transmitter locations with a correspondingly increased technical staff.

After careful consideration of operating costs and program plans, some television stations have installed their film-projection facilities at their transmitter and their live studio facilities at a downtown location. This permits film operation at any time and live telecasting can be confined to times when a studio crew is available. However, it creates a minor film-transportation and make-up problem, and in some ways complicates the integration of film with live programs, since the film-camera monitors cannot be economically duplicated at the studio. This latter objection applies particularly to the preview of visual effects by the producer or director at the studio prior to their use in an integrated live and film program, but it is possible to integrate films and live programs very satisfactorily without the studio preview facilities by coordinating the operations through a private-line telephone. If

Presented on April 28, 1953, at the Society's Convention at Los Angeles by R. A. Isberg, Consulting Television Engineer, 2001 Barbara Dr., Palo Alto, Calif.
(This paper was received first on May 11, 1953, and in revised form on August 28, 1953.)

film-projection facilities are provided at both the transmitter and the studio the remaining problem is only the film make-up and transportation for the portion of the day when film is utilized exclusively from the transmitter.

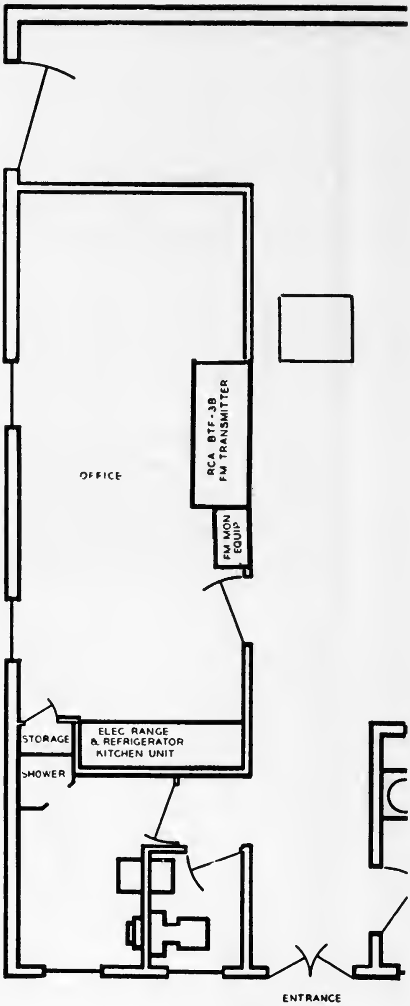
Initial Planning Considerations

In planning a television station and determining its staff requirements it is necessary to define the responsibilities of each staff member and to select and lay out the facilities so that the contemplated program schedule can be fulfilled. The small station's operating requirements are usually quite simple and can be adequately handled by combining some of the operating responsibilities to save manpower. In some instances, the purchase of additional equipment will reduce the staff requirements, and a choice may be made between spending a salary in a short period of time or amortizing an equivalent investment in equipment over a much longer period.

Inefficient initial planning will lead to difficulty in the later modification of existing operating practices because of possible opposition on the part of labor unions or fear on the part of the employees that the standard of operation may suffer. A new organization entering the television field is not bound by convention or contract with respect to the duties of its employees and it is therefore free to establish its business as it chooses. The employees will be as anxious as the management to create a new business which will profit and with which they will be proud to be associated, but they will look with alarm upon any attempt to reduce personnel requirements through the modification of an existing plant.

Analysis of Operating Functions

The requirements for the various technical operating functions in a television station are easily analyzed. The audio levels of sound on film programs have been previously monitored and the same is true of programs originating by a network or at a remote or studio broadcast. Therefore, except for program switching and initial level adjustment an audio man at a transmitter has little to do unless he is playing a record, making a recording, or monitoring a studio program. His attention may be intense for a few seconds or minutes each hour but the remainder of his time can be utilized for other duties.



The transmitter man has little to do

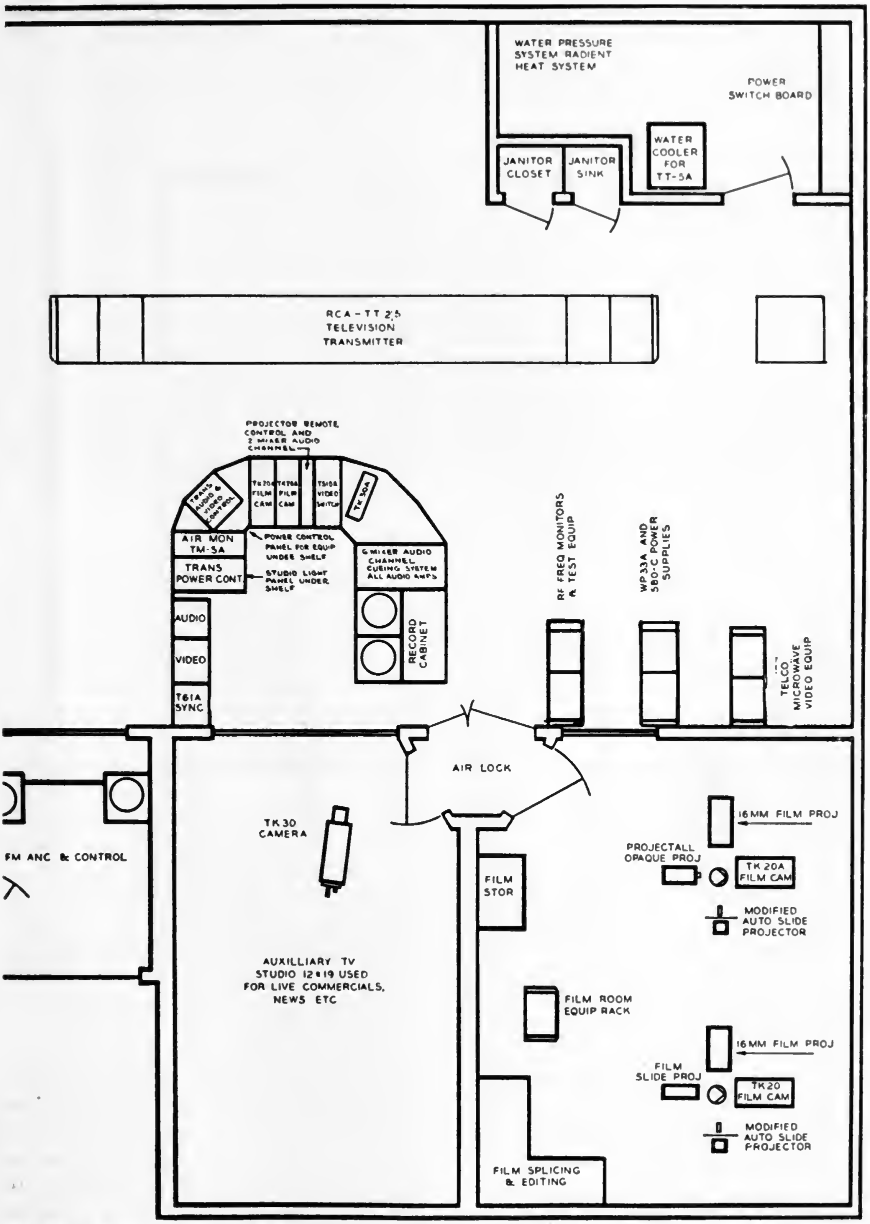


Fig. 1. Floor plan of KRON-TV transmitter building on San Bruno Mountain, showing the arrangement of its facilities. The audio and video control equipment is arranged in a U-shaped console in the transmitter room. The film equipment in the adjacent room is remotely controlled and is usually unattended. The auxiliary live studio is used for late-at-night programs. The main studios and offices are located in downtown San Francisco.

other than to check filament voltages, read the essential meters, be cognizant of the operating condition of the transmitter and to keep the FCC engineering log. The duties of audio switching and monitoring as well as the responsibility for the transmitter can be assigned to one man provided the audio equipment is located in the transmitter control room.

The addition of a video program source such as test pattern or microwave to the same man's responsibilities is no hardship provided the switching equipment for video and audio are conveniently arranged.

If film or live-camera programs are to originate at the transmitter it will be necessary to provide another man because the combination audio and transmitter man will not be able to devote enough time to shading and video levels unless the video programs are short. However, film programs of approximately ten minutes in a one-hour period may be handled by one combination audio-video-transmitter man provided the switching sequences are simple, and the film-camera control unit is conveniently located adjacent to the audio equipment in the transmitter room.

If the projection equipment is noisy, it should be located in an adjoining acoustically treated room and should be operatable by remote control. If quiet equipment is available, it may be located in the control room near the console. By careful program planning and by providing remotely controlled motion-picture and automatic slide-projection equipment as well as specially designed 95-min film reels, the manpower requirements for the film room can be reduced to only the loading of the projectors between shows. This can be easily accomplished by either the audio man or the video man during the course of a program.

Emergencies such as lamp failure in the projectors, loss of film loops, tearing of splices, etc., are relatively infrequent and can be controlled by replacing the lamps before they have been used for their expected life and by careful inspection of the film for torn sprocket holes, poor splices, etc. It is desirable to assign a person to film-room duty if the film operating load is heavy, and if opaque projection equipment requires frequent changing of slide material. It is also desirable for the person assigned to film-room duty to be responsible for the make-up of the film programs but if the film room is not easily accessible to public transportation or air express delivery service this work may have to be done at a downtown studio. In actual operating practice it is usually possible to utilize a maintenance man for film-room duty during periods of peak activity.

Description of KRON-TV

KRON-TV in San Francisco is an example of a station which was planned for maximum utilization of manpower without sacrificing operating standards. The floor plan and facilities arrangement of the transmitter building are shown by Fig. 1.

Prior to construction, the functions of the personnel were carefully analyzed and the equipment was laid out in a full-scale mock-up for operational analysis. After construction of the station, several small modifications of the plan have been made to suit operating convenience, but several years' successful operation has shown the plan to be sound, and the personnel are contented and have developed additional labor-saving innovations.

All equipment having controls is located in the U-shaped operating area designed for two-man operation when programs originate at the transmitter as shown in Fig. 2. During test pattern, downtown studio programs or network, only one man was initially required and he was responsible for the television transmitter, the film cameras, microwave facilities and audio equipment. Later additional operating requirements and other considerations resulted in the scheduling of two men during all broad-

Fig. 2. The KRON-TV control area, seen from the auxiliary studio.

cast periods. The second man is responsible for video control and the loading of the projection equipment. When a live camera in the transmitter studio is utilized, a third technician is assigned to operate it. The transmitter studio is only 12 × 19 ft in area, but it is very adequate for live demonstrations using simple props and title cards. This studio is used principally for live commercials late at night, on holidays and week ends when the two large downtown studio facilities may not be available. Only one five-man studio crew was initially required to cover the entire week's live programs from the downtown studio.

Live programs are broadcast nightly from the transmitter studio utilizing one camera. This camera is usually kept in motion to add interest to the live program. It is regularly used in conjunction with 3-min film shorts featuring orchestras and talent, interspersed with a live master or mistress of ceremonies.

A staff announcer-producer is assigned at the transmitter during evening operating periods or when the downtown studio is not in operation. He is responsible for the program log, station identification and coordination of programs. Additional talent is customarily used for commercial demonstrations.

The left end of the U-shaped operating area includes the rack mounted equipment minus the power supplies. The studio-type synchronizing generator is contained in one rack; the video equipment including two microwave receivers, two stabilizing amplifiers, a video jack panel and two distribution amplifiers comprise an adjoining rack; and the audio equipment including the limiting amplifier, pre-emphasis network, magnetic tape recorder, audio jack panel, audio equalizer, and video bar generator is located in a third rack. The transmitter power console is next, and the space below the operating shelf is utilized for a studio lighting switch panel so that the technicians have control of the preset lights. Next is the "on the air" picture and waveform monitor, and then the transmitter audio-video control panel. Under the operating shelf of this console are located the power switches for the video and audio equipment. An intercommunication panel for talking to the film room, the studio, the office, shop and front door is located between the

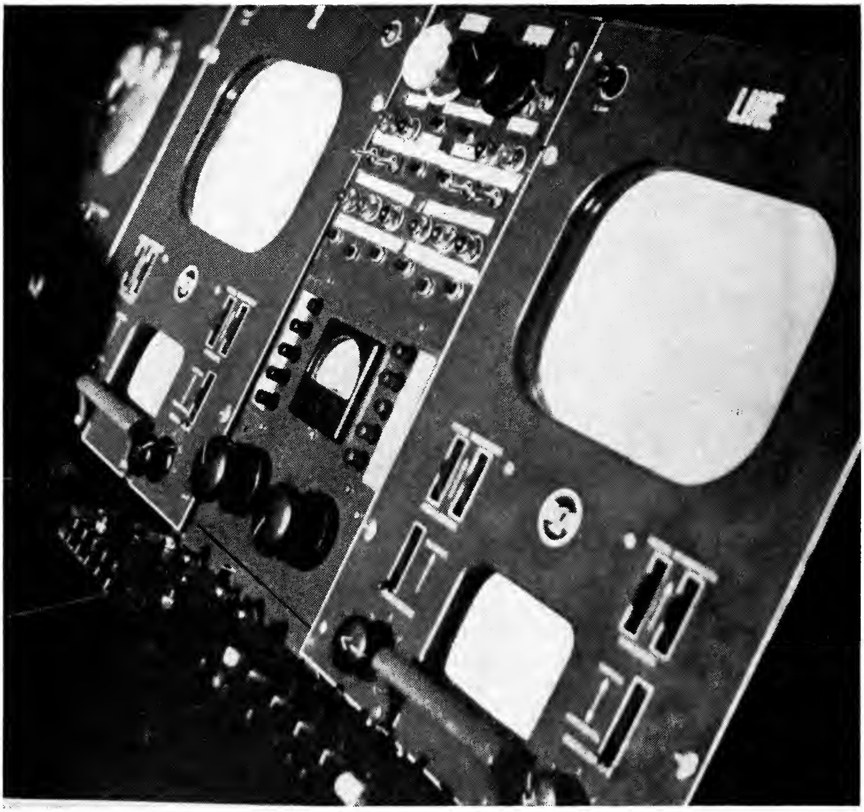


Fig. 3. Close-up of the projector remote control and two-channel audio mixer panel, located between the line monitor and film camera No. 2. The two large knobs at the top control variacs for the fixed slide-projector lamps; the upper bank of switches and tally lights are for controlling the automatic slide projectors; and the lower bank of switches and tally lights are for controlling the 16mm motion-picture projectors.

The lower part of the panel has two audio mixers, each with a choice of five inputs selected by pushbutton, and a VU meter. Below the audio mixer is a panel providing remote Start and Stop buttons for the two turntables and a magnetic tape recorder.

transmitter audio-video control panel and the control consoles for the two film cameras. Adjacent to the second film-camera control is a special console (Fig. 3), containing two variacs for the slide projectors, controls for the two automatic and fixed-slide projectors and the opaque projector, remote controls for the two 16mm film projectors, and a two-mixer audio channel providing a choice of ten audio inputs. This audio console permits one-man operation of video and audio switching since it places faders, selector switches, and remote controls for starting and stopping the turntables and magnetic tape recorders within easy reach of the operator. Since two men are usually available, the one-man operation is infrequently used. The video switcher and program monitor is next in line followed by a field-type camera control unit for the studio

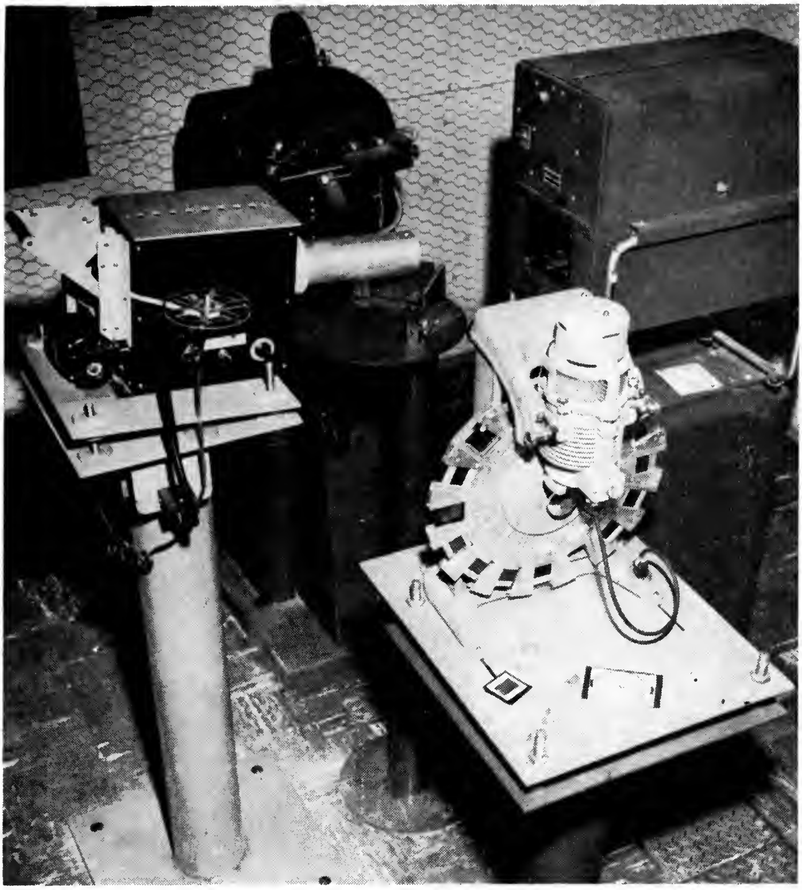


Fig. 4. One of the KRON-TV film cameras is used in conjunction with a 16mm film projector, a remotely controlled turret-type 2 × 2 slide projector, and a "Projectall" opaque or baloptican projector. The opaque projector is utilized to project a $\frac{5}{16}$-in. news tape over the bottom side of a test pattern. The bottom of the test pattern is masked out with opaque tape and is projected as a transparency through the automatic slide projector. The news tape is projected as an opaque against a black background and is optically superimposed on the test pattern. The light intensities of the projectors can be controlled by variacs so that optimum reproduction will result.

camera. Relay switching of the audio and video simultaneously has also been installed in the RCA TS10A switcher.

Completing the "U" on the righthand side is a six-channel audio console containing the equivalent of a relay rack full of audio equipment, all of the plug-in variety, and two turntables with special cuing systems and modifications for remote relay control.

The audio system provides two separate program channels, one for the two-channel mixer and the other for the six-channel mixer, and the outputs of the two channels can be combined to feed the transmitter. This flexibility is also

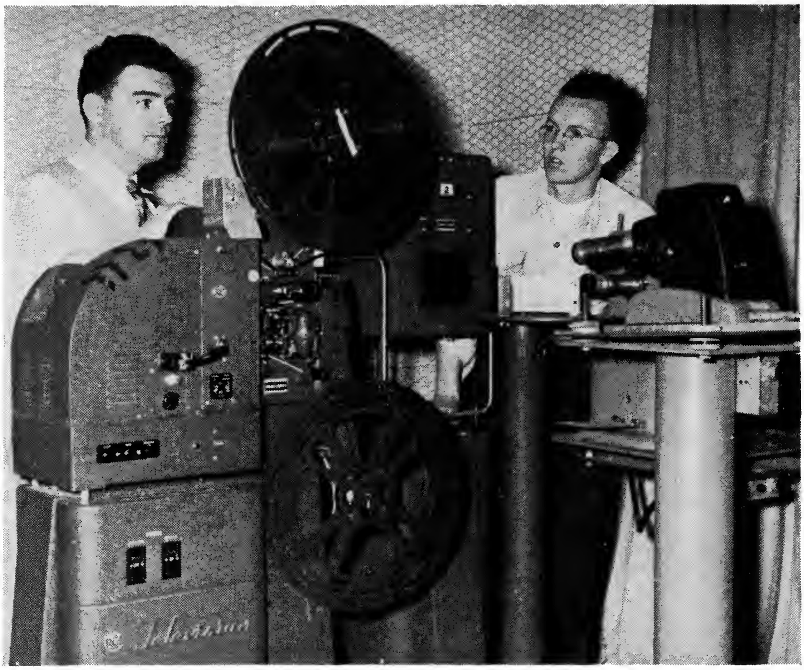


Fig. 5. The 95-min 16mm film reels are shown on the RCA modified TP16B projectors, with Bill Sadler, left, formerly KRON-TV supervisor, and Donald Anderson, KRON-TV engineer. This second camera is used with a 2 × 2 slide projector and an automatic slide projector.

utilized in playing recordings through one channel feeding a speaker in the studio, so that an artist may sing to the accompaniment of a recorded orchestra without danger of acoustic feedback since his voice is amplified by a separate channel.

The film-room equipment at KRON-TV is remotely controlled and is nearly automatic in operation. The automatic slide projectors (Fig. 4) have been modified for remote control from the operating console, and special cams and reversible motors have been installed. Thus it is unnecessary for a man to be in the film room to change slides and since each automatic projector is associated with one film camera, the video operator can easily preview and shade each slide before switching it on the air. The film-room equipment is laid out for maximum efficiency and continuity of operation. Since duplicate equipment is provided, protection in case of equipment failure is assured.

The original RCA TP16B 16mm film projectors have been modified by extending the reel arms and by providing specially designed Goldberg 95-min film reels as shown in Fig. 5. The new Eastman projectors are designed to be used with 4000-ft reels. Thus a one-hour kinescope recording or film feature may be spliced to film station identifications, film spot announcements and another half-hour show and run continuously on one projector. The film editing and make-up are done by the program department downtown, and the film is delivered to the technicians at the

Film Camera	Time	Program	Visual Source	Aural Source
1	9:29:30	Sponsored Announcement (20)	F	SOF
6 (black leader)				
1		Station Identification (10)	XA-2	BM
			Studio B	
1	9:30–9:50:30	*Frisco Frankie*	Open 1 Cam	SM ET672
			F	SOF
6 (black leader) 2	Approx. 9:43	Film Commercial (60)	F	SOF
			Close	
			1 Cam	SM
6 (black leader)				
1		Sponsored Announcement (20)	F	SOF
1		Sponsored Station Identification (10)	F	SOF
			Studio B	
1	10:00–10:29:30	*Files of Snoopy Smith*	F	SOF
6 (black leader)	Approx. 10:16	Live Commercial (60)	Live	
			2 Cam	Boom
2		Public Service Announcement (20)	XB37	BM
1		Sign Off (10)	XA-2	BM

Fig. 6. Example of Operating Work Schedule.

Explanation of Fig. 6

Line at left shows film-splicing order as assigned by the video-control supervisor; during this time segment all film is on one reel with black leader spliced in as indicated by wavy line (number of seconds of black leader indicated by adjacent number). Black leader provides time to stop and start projector for station identification, commercial or another program. The Sponsored Announcement (20-sec duration) at 9:29:30 is a film (F) and the audio is sound on film (SOF). The Station Identification is from a slide (XA-2) with an aural announcement from the announce booth microphone (BM). It is projected while a 6-sec black leader, spliced between the sponsored announcement and the feature film, is run through the film projector and is stopped. The opening live commercial is done on one camera (1 Cam) with a studio microphone (SM) and an electrical transcription ET672 for a theme. The film feature is started on a cue from the Program Director and runs until 9:43 when a 6-sec black leader provides time to stop and start the projector for a one-minute film commercial in film camera 2 having sound on film (SOF). The close of the program is also live and another 6-sec stop down black leader provides time to stop and start the projector.

Following the closing live commercial, the projector is again started on cue to present a 20-sec sponsored announcement, a 10-sec sponsored station identification both with sound on film (SOF) and the next feature film. At approximately 10:16 a 6-sec black leader provides time for stopping and starting the projector for a live one-minute commercial requiring 2 cameras and a microphone boom. Following the commercial, the film feature is resumed on cue from the Program Director, and at its conclusion, a slide XB37 in camera 2 and a sign off slide XA-2 in camera 1 with audio from the Booth Microphone is utilized.

Fig. 7. After films are checked in by the station, the reels are placed in bins to await preview screening. The bins are arranged in vertical rows by the day of the week, with shelves marked for the hour the film is to be shown.

Fig. 8. Facilities for editing and splicing 16mm films. Each splicing table is equipped with one motor-driven rewind and one hand-cranked rewind. The film is spliced in accordance with instructions from the video-control supervisor as noted on the left margin of the daily work schedule shown in Fig. 6. Reel sizes are selected for the particular operating requirement.

transmitter by a messenger service. Facilities for the film make-up are included in the transmitter film room, and all technicians are familiar with the techniques.

Film Program Coordination and Responsibility

In order to achieve a semiautomatic film-room operation, it was necessary to devise a simple and complete operating work schedule. A simplified version of the schedule is shown in Fig. 6.

This work schedule was designed by KRON-TV technical operating and program personnel and includes all the necessary information regarding any equipment or facility requirements for a given program. The schedule is prepared several days in advance of the broadcast day by the Traffic Department from information supplied by the Sales and Program Departments. It is submitted to the transmitter video-control supervisor who checks the schedule with respect to film and slide equipment and personnel requirements and for any situations which are apt to cause operating difficulty. Such situations might be the scheduling of the use of a 35mm film-strip or opaque projection material at times when only two technicians are assigned at the transmitter. Such a situation may require the scheduling of another technician to cover the film room since the film-strip and opaque projectors are manually operated. Their use is infrequent, hence there has been no need for adding automatic features to them.

While checking the work schedule, the video-control supervisor marks it to assign the slides to the remotely controlled slide projectors and to indicate the desired splicing order for the various films. It is common practice to have a 10-sec film station identification spliced to a 20-sec commercial spot which is in turn spliced to a feature film or kine recording. With the large reels, over an hour and a half of film including spots,

Fig. 9. When the reels are ready, they are placed in these "cans" which are then locked and shipped to the station's transmitter by a messenger service. Transcriptions, records and mail are also inserted in these "cans."

station identifications, etc., can be spliced together. This work is normally done by full-time film editors at the downtown studios (Figs. 7 and 8). The responsibility for the receiving, inspection, cleaning, editing, splicing and shipping of the film is thus principally that of the program department, and the technicians treat the prepared film program material as though it were a transcription. The degree to which the large reels are used and the amount of splicing required depends upon the availability of technical personnel. If an extra man is available for film-room duty, he can be assigned and the film room can be operated on the basis of numerous short reels in succession. However, the smooth integration of 10-sec and 20-sec commercials into a 30-sec station break is greatly simplified by splicing them to the longer films.

In the event that a program change requires that a film be moved in the schedule, deleted or substituted, such a change is easily made since splicing equipment is available at the transmitter film room. In fact, it is not uncommon for numerous spots which are used during the Friday program to be removed by the technicians and spliced to the Saturday or Sunday film. Last-minute rearrangement of slides, or any other equipment requirement, has never created serious scheduling problems.

Television Film and Splicing Practices

The same spots and station identifications are used many times. Since they are customarily spliced by cementing them to another film, they frequently are supplied with opaque leader at both ends. These leaders are initially trimmed to 6 in. and a number of splices can be made before it is necessary to add additional black leader for splicing. Each splice results in the loss of one frame-width of film. Obviously if the splicing was not done on the opaque leader, the film would soon lose either visual or aural content.

Operating experience has indicated that splices should not be spaced closer than 3 in., otherwise there is danger of splice breakage. Some spots are supplied with "hen scratches" or writing on the black leader. This must be masked out. Black cellophane adhesive tape has been found to be suitable for such masking.

Blooping Sound Tracks. Sometimes it is necessary to "bloop" a sound track to overcome an objectionable noise when a splice passes through the sound head. A triangle of black cellophane tape applied over the sound track has been found very effective. Commercial bloop inks require more time because they must dry and they are most effective if applied with a spray gun and a mask. In practice a good audio man can minimize "bloops" with his fader after a few days' experience. He must, of course, know when they will occur in order to anticipate them.

Stop-Down Leader. In many instances it is necessary to insert an appropriate length of opaque leader in the film makeup to provide for the showing of another film or slide while the film projector continues to run without interruption. When it is necessary to stop a projector to show another film on another projector or to utilize another source of program material, approximately 4 ft of opaque leader is spliced in the film makeup to allow for stopping and starting the projector. Such a leader would be "cue" marked in the middle by the punched hole method.

Cue Marks. Adequate cue markers for 16mm film have not been generally available. The customary hole punches are large and are objectionable to the viewer. A small cue marker which punches four frames in the upper right-hand corner, outside of the television receiver mask area, has been made on a custom basis and an aural cue marker utilizing prerecorded adhesive magnetic tape will soon be available. The aural cue marker will create a signal which only the station personnel can hear and will therefore overcome the objectionable features of the visual cue.

Film Splicing Technique. Good cemented film splices are easily made and require only simple techniques which must be thoroughly understood and appreciated. The Griswold R-3 Splicer is very adequate and is used by many television stations. It is essential that the emulsion on the film be carefully scraped clean. This is easily done by clamping the film in the splicer and shearing it, then the end of the film is moistened and scraped with a well-honed scraper. The scraper must be kept sharp and clean or it will not do a good job. Care should be used not to scrape away the film base or the splice will be weak. The splicer should be well illuminated to facilitate inspection of the splice.

The film cement should be fresh and

should be kept in small bottles which should be tightly capped when not in use. Film cement is composed of very volatile chemicals which are essential for dissolving the film base. Eastman Film Cement has been very satisfactory. Most stations purchase cement in large bottles from which they refill the one-ounce bottles used at the editing table.

After a thin coat of cement is applied, the splice is clamped in the splicer for 10 sec. Then one side of the splicer is opened to admit air for another 10 sec of drying. The splice is then wiped clean of excess cement.

Film Cleaning. Much of the film supplied to television stations has been handled several times and has accumulated dirt, lint and hair. Film cleaning can be easily accomplished in commercial film cleaners utilizing a solution that cleans the film and also deposits a thin layer of wax on it for protection, or small quantities of film can easily be cleaned with soft powder puffs or velvet pads saturated in carbon tetrachloride containing a small amount of beeswax. It is necessary to ventilate film-cleaning areas since the fumes of the cleaning solvent are toxic.

Maintenance of Projection Facilities. All film-projection equipment should have regular maintenance to insure that it is clean and well lubricated. Most stations find it desirable to have one man assigned to maintain projection equipment as well as have the services of a manufacturer's service organization. It is essential to have compressed air available near the projectors to blow lint or hair out of the film gate during operation and for use during maintenance.

Film Department Staff. In addition to the technicians who operate the station, KRON-TV presently has a film-room staff of three splicers, one editor and a shipping and receiving clerk who also has other duties. The editor times film features and edits them to fit into given broadcast periods with their respective commercials. A messenger service is utilized to transport the film to the transmitter film room, which is on San Bruno Mountain approximately ten miles from the studio by road.

Conclusion

Through coordination in scheduling programs and assigning appropriate facilities, it is possible to operate a television station with essentially unattended film-projection equipment. However, consideration must be given to possible film-room emergencies which can be covered by a man who is normally assigned to maintenance.

The number of technical operating personnel of a television station can be kept small by combining some of their operating functions. Film-projection facilities installed at a transmitter plant will reduce the number of studio personnel required. However, each station's situation should be analyzed with respect to other convenience and cost factors such as program coordination, distance and condition of roads.

The methods of operation, as described in this paper, were developed by the management and staff of KRON-TV while the writer was its chief engineer. Credit is especially due to H. P. See, Manager of KRON-TV, for the inauguration of these policies, and to J. L. Berryhill, KRON-TV's chief engineer, for his assistance in preparing this paper.

Discussion

Harry R. Lubcke (Consulting Engineer): Would you say, on the basis of KRON's experience, that, if the studio were supplied with one of the remote-controlled cameras, the men would have time to manipulate that also?

Mr. Isberg: Oh, yes. These practices which I've described for KRON-TV mountain operations certainly apply to studios. In other words, I have described a divided studio and transmitter operation having film facilities and a one-camera studio at the transmitter. This camera is electrically adjusted from the operating console in the transmitter room. Possibly I still don't understand your question.

Mr. Lubcke: No, I don't believe you do. There is a certain organization, with which I have no connection, which manufactures a camera that can be panned and tilted remotely by automatic control and I was wondering if these men of yours would have time enough to use that in a practical way?

Mr. Isberg: Since I've had no experience with it, I'm not sure. A cameraman is normally assigned to the transmitter studio, but if someone, possibly the program man, were operating the remote controls of a remotely controlled camera. that was dollying itself around the floor and panning, and so forth, it might be all right.

Mr. Lubcke: May I put the question this way. The technicians have a little spare time. Could they use this equipment if they had it?

Mr. Isberg: There isn't very much time for additional technical duties as we presently operate. But by slight modifications of program formats and procedures they could probably learn to use the remotely controlled camera.

A Mathematical and Experimental Foundation for Stereoscopic Photography

By ARMIN J. HILL

The system of stereoscopic photography developed by the Motion Picture Research Council, and now generally used in the major Hollywood studios, has been based upon extensive experimental data regarding the processes involved in binocular vision. It is now known that this vision does not give absolute location of points in space, but rather that it is sensitive to small differences in distance and direction. Therefore, it appears logical to use differential rather than integral forms in calculating probable appearances of projected pictures. It is found that this approach removes many of the troublesome restrictions found in suggestions based upon other assumptions. Perspective and apparent depth can be balanced for pictures seen from the better viewing positions in motion-picture theaters. It is also possible to include necessary psychological factors to allow satisfactory photography of close-ups and other special effects. The result is that if certain simple limitations and precautions are observed, it is not difficult to obtain stereoscopic motion pictures which are consistently natural in appearance and easy to view.

The Motion Picture Research Council has developed a system of recommendations for the photography of stereoscopic motion pictures which in many respects is quite different from most of those which have previously been suggested. Therefore it is desirable to review the basic theory of the transmission and viewing of stereoscopic pictorial information in the light of what is now known about the processes of binocular vision in order to show that the Research Council system has been established on a sound theoretical basis and that it has been possible to determine the necessary constants experimentally in such a manner that they can be considered reliable.

These recommendations have now been used in critical comparative tests in many of the studios and have found enough application in actual production to show that they are capable of giving excellent results. In fact these results have adequately demonstrated that the approach which has been used is correct, and that the mathematical foundation on

Parts of the subject matter of this paper were presented on October 9, 1952, at the Society's Convention at Washington, D.C., and on April 28, 1953, at the Society's Convention at Los Angeles, by Armin J. Hill, Motion Picture Research Council, 1421 North Western Ave., Hollywood 27, Calif.
(This paper was received September 8, 1953.)

SYMBOLS

Note: In general primed symbols refer to quantities in the projected image space (in the theater) corresponding to the unprimed quantities in the object space (before the camera). The subscript o is used when quantities are referred to the apparent position of the observer when this does not coincide with the camera position.

a	Distance from plane of convergence to object
b	Interaxial spacing of camera lens
e	Interocular distance of observer
f	Focal length of camera or lens-film distance
f_p	Focal length of projector lens
G	"Giantizing" factor in general equation
m	Magnification as given by w'/w
$\bar{m}$	"Reduced" magnification as given by $m(b/e)$
M_s	Screen magnification as given by W_s/w_p
p	Distance from camera to plane of convergence
s	Integrated angular distance in perceptive space
u	Width of object not in plane of convergence
v	Distance from observer to theater screen
w	Any horizontal distance in the plane of convergence
w_p	Width of projector aperture
W_s	Width of projected picture on screen
θ	Angle of elevation in bipolar coordinates
ϕ	Bipolar latitude
γ	Bipolar parallax or angle of convergence
η	Distance factor
ρ	Distance (or nearness) ratio
σ, μ	Luneburg Constants
τ	Modified bipolar parallax given by $\sigma(\gamma + \mu)$

which it rests will probably serve as well in solving future problems in this type of photography as it already has in solving some of the more basic ones.

The Research Council System

The system of recommendations developed by the Research Council is characterized by several features which are either different, or which are treated differently from those in other systems. The more important of these are:

(a) *Use of a relatively, but not absolutely, fixed interaxial spacing:* The interaxial spacing is found to be related to the focal length of the lenses rather than to depend only upon the distance from camera to object. Therefore it is varied in a manner quite different from other stereographic systems.

(b) *Allowance of limited divergence in lines of sight:* Lines of sight to background points can be allowed to diverge slightly. The amount of this divergence is strictly limited in accordance with reliable data from numerous optometric tests, and a factor of safety is allowed so that no one with normal vision will have any difficulty viewing such points. However this slight divergence allows a freedom of camera setting and motion not possible with most of the other systems.

(c) *Establishment of forescreen reference planes:* Two reference planes are established for control of forescreen action. One of these is the limit for maintaining good proportion in the appearance of the projected picture. The other limits the distance objects can be forescreen and still be seen distinctly.

(d) *Special treatment of close-ups:* The psychological effect of the close-up has been taken into account to make possible very acceptable close-up photography.

(e) *Special formulation for distant shots:* The general formula which has been developed shows that distant shots require a somewhat special treatment. This has been applied with very satisfactory results.

(f) *Use of "normal" procedures on the set:* Perhaps one of the most distinctive and desirable features of this system is that it requires few changes in accepted camera techniques. The cameramen and assistants handle all the necessary calculations. Distances are measured from the camera in feet and inches. Camera motion is used in about the same way as it has been for "flat" photography. Long, medium and close shots are used in about the same proportion, and the use of different lens focal lengths can be very similar to that which has previously been accepted as good practice. In short, most of the techniques which are already well known to experienced cameramen can be used with good effect in this new medium.

In addition to these special features, this system has several which are common to most of the other systems of stereoscopic photography. Among these may be mentioned:

(a) The establishment of a "plane of convergence" in the set which will correspond to the plane of the screen in the theater.

(b) The establishment of geometric image positions according to generally accepted principles of stereoscopic transmission.

(c) The use of sheet polarizers in projector filters and viewers, use of dual cameras and double film in taking the pictures and (at present) of double synchronized projection, with individual viewers required for each spectator, all of which are common to most of the systems being used successfully in the presentation of stereoscopic pictures to theater audiences.

How Does This System Differ From Others?

Most of the systems which have been proposed for the photography of stereoscopic motion pictures are based on the assumption that binocular vision gives an absolute estimate of distance and a definite indication of the angles taken by the lines of sight in viewing an object. It is therefore necessary to have the projected image points so related to each other that lines of sight for a spectator in the theater will have the same direction as the corresponding lines for the taking camera.

An immediate consequence of this assumption is that the interaxial spacing must be proportional to the distance from the camera to the object, and in most of the suggested formulae the required spacing is so small for practical taking distances and reasonable screen sizes that the results invariably show the distortion referred to as "cardboarding" wherein the objects appear to be flattened into distinct planes at varying distances from the camera.

Another assumption which has been made quite generally and which has some experimental justification is that under no conditions should lines of sight to corresponding image points ever be allowed to diverge. It can easily be shown that this assumption makes impossible the photography of "deep" scenes and their subsequent projection upon full-sized theater screens unless the interaxial spacing is again reduced to such an extent that "cardboarding" is apparent.

Modern research in the process of binocular vision has adequately shown that such vision does not, of itself, give much information on the absolute distance of an object from the eyes. Neither is there any mechanism in the visual processes which indicates the angles of the lines of sight. On the other hand, binocular vision gives a very sensitive indication of relatively small *differences* in distances and of small *differences* in the directions of the lines of sight. It is these differences which are used to give the binocular depth effects upon which successful stereoscopic photography depends. Therefore any theory which is to give successful results must logically be based upon these differences of distance and direction rather than upon total or absolute values.

When such a theory is used, it becomes apparent that the binding limitations of the other assumptions are no longer valid. The interaxial spacing need not be proportional to the taking distance, and since the eyes cannot detect the actual directions of the lines of sight, there is no real reason that these lines cannot diverge slightly. It is therefore possible to photograph pictures in such a manner that all dimensions of an object will *appear* in natural proportion, and these proportions can be balanced with the perspective so that within acceptable approximations, at least, the projected stereoscopic pictures will appear as the natural scene did from the apparent camera position.

The projected picture will no longer have the same geometric proportions as the natural scene, but will *appear* to have them when viewed from the better positions in an average theater. Distortions which are caused by viewing the picture from an angle, as from a side seat, or which vary with the viewing distance, of course cannot be eliminated. However, it can be shown that over a comparatively large viewing area stereoscopic pictures can appear to have very acceptable proportions. This is quite definitely in contrast to the concept of the "orthostereoscopic" position based upon the strictly geometric assumptions of other systems.

In order to obtain the proper effects, clues which may reveal the absolute distance to projected image points must be suppressed, and it may not always be possible to do this. Then it becomes necessary to take the conflicting effects into account and work out an acceptable compromise.

Experience has shown that in most actual situations the theory which is presented here gives effective and satisfying results. Necessary modifications can be made without guesswork or extensive testing. Most important of all, the results appear natural and are easy on the eyes, giving a very pleasing overall effect.

I. THE BASIC FORMULAE FOR STEREO-TRANSMISSION

The Three Spaces

It is convenient in discussing the principles of stereo-transmission to speak of the *object space* as that in front of the camera, the *projected image space* as that containing the geometric image positions in the theater, and the *perceptive*, or *apparent image space* as that containing the image points as they appear to be related to each other in the perception of the spectator. In this portion of the discussion we shall be interested in the relationship between the object space and the projected image space. Later we will show how the transformation can be made into the perceptive image space so that we can predict approximately the results as they will appear to the observer.

The Plane of Convergence

First, let us determine those reference points which are common to both the object and projected image spaces. If two projectors are properly aligned and used to project identical prints on the screen simultaneously, these prints should exactly overlap — at least at the center. Accepted practice now uses this same alignment for projecting stereoscopic pictures. Since these prints are each guided from one edge, this means that corresponding point pairs which are exactly the same distance from these edges will exactly coincide on the screen, and will therefore appear to be in the plane of the screen.

A little consideration will show that such point pairs will represent object points which are in an approximately plane surface at some distance in front of the camera, and perpendicular to the direction in which the camera is pointed. This assumes of course that the lenses are properly matched and that other factors are such that the two pictures are very nearly the same size.

Let us refer to this (approximate) plane in the object space which contains those points whose stereoscopic image point pairs coincide at the plane of the screen in the image space, as the *plane of convergence.*

Principal and Photographic Axes

Now let us define the principal stereoscopic axes of the two lens-film systems in the stereoscopic camera as those optical rays drawn through the lens nodal points from the points on each film which will be projected at the center of the screen. These will not necessarily coincide with the optical axes of the systems. However if they are extended far enough into the object space, they will intersect in the plane of convergence. The angle between these two axes is known as the convergence angle, or sometimes as the convergence parallax.

Of more practical use to the cameraman are the *photographic axes*, which are defined as those through the centers of the equivalent projector apertures in the camera film plane and the nodal points of the respective lenses. These axes will coincide with the principal axes only when the position of the film relative to the camera lens, the handling of the film through processing, and the alignment of the projectors are all such that the projector aperture as outlined in the camera ground glass coincides with the area of the film which is actually projected on the screen.

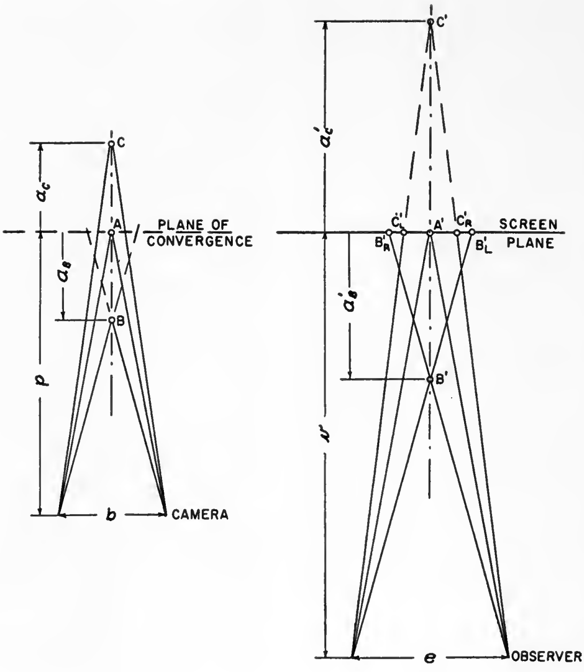
The Plane of Convergence and the Screen Plane

In order that the photographic and principal axes will be coincident, and therefore that the intended plane of convergence will actually coincide with the screen plane, it is customary to align the cameras so that their photographic axes coincide on some well-defined vertical object which is in the intended plane of convergence. If the stereoscopic images of this object then coincide when projected on the screen, it is known that the axes are properly aligned and that alignment has been maintained through the film processing and projection.

With the definitions we have given, it is apparent that the plane of convergence in the set (object space) becomes the plane of the screen in the theater (image space). Furthermore, unless correction is to be made in processing or projection, this plane will be that containing the points upon which the photographic axes of the camera actually converge. Therefore it is convenient to use it as the basis for the mathematical relationships between the object and projected image spaces.

A plan view of the geometry involved in this relationship is shown in Fig. 1. Here three points are represented along a line from the camera perpendicular to the plane of convergence. Point A is at the plane of convergence in Fig. 1 (a), and so its two image points coincide at the screen in (b). Point B is nearer the camera and its image points are therefore doubled so that the one seen by the right eye (B'_R) is to the left of the one seen by the left eye (B'_L). The lines of sight from the observer at point O will therefore intersect at (B') which is the *geometric image point* of the object point B. The point C is beyond the plane of convergence. Therefore, (C'_R) is to the *right* of (C'_L), and the lines of sight intersect behind the screen plane at the image point C'.

Let us use p for the distance from the camera to the plane of convergence and a (with suitable subscript) for the distance from this plane to an object point. In the image space, let v represent the distance from observer to screen, and a' the distance from the screen to the image point. (In each case distance away from the camera or observer is considered positive, that toward them negative.) The interaxial spacing of the camera lenses (distance between front nodal points) is indicated by b. The



(a) (b)

Fig. 1. Lines of sight in taking and viewing stereoscopic pictures.

interocular of the observer is e. Any width (or other dimension in the plane of convergence) will be designated by w with an appropriate subscript when in the object space and by a corresponding w' in the image space. Focal length of the camera lenses will be designated by f, and this will also be used to designate lens-film distance, since for all but a few special cases this will be effectively the focal length. The focal length of the projector will be designated by f_p.

Magnification

The *screen magnification*, M_s, is the ratio of a linear dimension in the projected picture on the screen to the corresponding dimension on the film. It can be found by dividing the projection distance by the lens-film distance in the projector, or for practical purposes by dividing the projection distance by f_p. It may also be found by dividing the width of the projected picture on the screen (without masking), W_s, by the width of the projector aperture, w_p, which for standard projection is 0.825 in.

A more convenient quantity in the mathematical development given here is the overall *magnification* of the photographic-projection process. This will be designated by m and is defined as the ratio of a linear dimension of an image in the plane of the screen to the corresponding dimension in the plane of convergence. For example, if a man 6 ft tall is photographed in the plane of convergence, and his projected image on the screen is 18 ft tall, the magnification is 3.

Distance Ratios and Factors — Nearness Ratios

Let us now refer to Fig. 2, which is

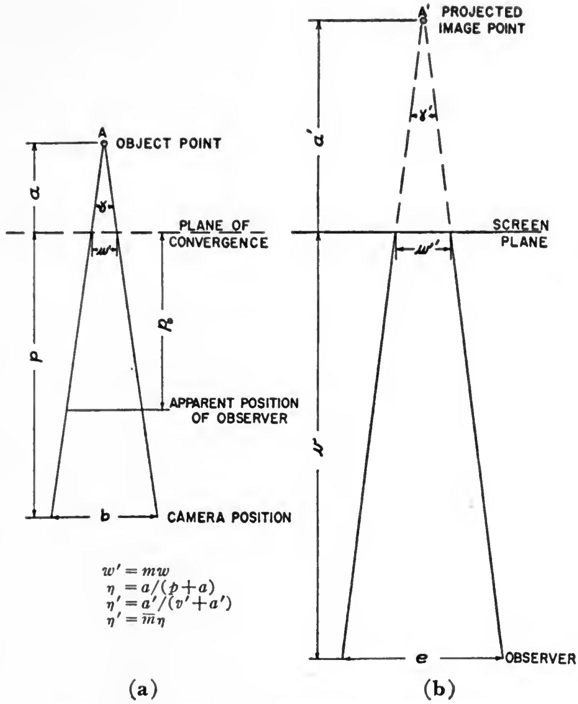


Fig. 2 Geometry of stereoscopic transmission.

similar to Fig. 1, except that it shows only a single point A which is at a distance a behind the plane of convergence. The point may just as well be in front of this plane, in which case a becomes negative, or at the plane of convergence in which case a is zero. It is seen that by using similar triangles

$$\frac{a}{p} = \frac{w}{w+b} \quad \text{and} \quad \frac{a'}{v} = \frac{w'}{w'+e} \qquad (1)$$

Let us designate the ratio a/p as the *object distance ratio*, and a'/v as the *image distance ratio*. When a' is negative, the absolute value of a'/v can also be referred to as the *nearness ratio*.

It will be noticed that the image distance ratio depends only upon the value of w' and e. Therefore it will be the same for all observers who have the same interocular, and since the interocular does not vary a great deal from one person to another, we can say in general that the image distance ratio is practically the same for all observers in the theater.

It is sometimes more convenient to use *distance factors* rather than distance ratios. These are given in the form

$$\eta = \frac{w}{b} = \frac{a}{p+a} \qquad (2a)$$

for the object space and

$$\eta' = \frac{w'}{e} = \frac{a'}{v+a'}, \qquad (2b)$$

in the image space.

The Basic Formula for Stereo-Transmission

Now, from the definition of the magnification we have

$$w' = mw \qquad (3)$$

Table I. Distance Factors and Ratios in the Image Space.

Geometric image position	Distance factor	Distance ratio	Spottiswoode's[1] nearness factor
At infinity	1	Infinity	0
At screen plane	0	1	1
0.5 way from screen to observer	−1	−0.5	2
0.8 " " " "	−4	−0.8	5

so that

$$\eta' = m(b/e)\eta \quad (4)$$

or in still simpler form

$$\eta' = \overline{m}\eta \quad (5)$$

where $\overline{m} = m(b/e)$ is known as the *reduced magnification*, or in the Research Council system simply as the "*M* value." We have here, then, a very simple and convenient expression which relates all the essential information in the projected image and object spaces. In other words, it is the basic equation of stereo-transmission between these spaces.

If we use ρ and ρ' to represent the distance ratios, it is easily seen that these are related to the distance factors by the equations

$$\rho = \eta/(1 - \eta) \text{ and } \rho' = \eta'/(1 - \eta') \quad (6)$$

and conversely

$$\eta = \rho/(1 + \rho) \text{ and } \eta' = \rho'/(1 + \rho') \quad (7)$$

Table I gives the distance factors and ratios for various points in the image space and compares them with the "nearness factors" suggested by Spottiswoode.[1] Note that the nearness ratio which we have defined as the absolute value of the distance ratio actually specifies the relative distance of the image point from screen to the distance of the observer from screen. Also, it is seen that the numerical value of the distance factor is one less than Spottiswoode's nearness factor.

One of the most noticeable effects when stereoscopic pictures are projected on full-sized theater screens as contrasted to their projection on the comparatively small screens used in

Table II. Nearness Ratios in Object Space for Different *M* Values.

Nearness ratio in theater	Nearness ratios in front of camera for given $\overline{m}$								
	$\overline{m}\to 1$	2	3	4	5	6	7	8	10
0.1	0.10	0.05	0.03	0.03	0.02	0.02	0.02	0.01	0.01
0.2	0.20	0.11	0.08	0.06	0.05	0.04	0.03	0.03	0.02
0.3	0.30	0.18	0.12	0.10	0.08	0.07	0.06	0.05	0.04
0.4	0.40	0.25	0.18	0.14	0.12	0.10	0.09	0.08	0.06
0.5	**0.50**	**0.33**	**0.25**	**0.20**	**0.17**	**0.14**	**0.12**	**0.10**	**0.09**
0.6	0.60	0.43	0.33	0.27	0.23	0.20	0.18	0.16	0.13
0.7	0.70	0.54	0.44	0.37	0.32	0.28	0.25	0.23	0.19
0.8	**0.80**	**0.67**	**0.57**	**0.50**	**0.44**	**0.40**	**0.36**	**0.33**	**0.29**
0.9	0.90	0.82	0.75	0.69	0.64	0.60	0.56	0.53	0.47
1.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: The ratios of 0.5 and 0.8 (in image space), shown in boldface, are those recommended as reference "near points" in the Research Council system. These are discussed more fully in a later section.

amateur photography is the distortion in any subject matter which comes fore-screen. The reason for this is at once apparent when we consider the relationship between the nearness ratios in the image and object spaces for theater screen projection. Using Eq. (5) and the relationship of Eq. (7), we find that

$$\rho = \frac{\rho'}{\bar{m} + (\bar{m} - 1)\rho'} \qquad (8)$$

from which we can tabulate the nearness ratios (absolute values of distance ratios) for the object space to give a specified ratio in the theater for various reduced magnification values. In most cases this reduced magnification value will be of the order of 3 or more, and for close-ups may approach 10. The small distance which any object can be toward the camera from the plane of convergence under these conditions is quite apparent from the values given in Table II.

II. THE TRANSFORMATION TO PERCEPTIVE SPACE

So far, we have considered only the geometric configuration of the image points in the projected space and their relationships to corresponding points in the object space. While these relationships are very useful in establishing certain important limitations which will be discussed later, they tell us but little about how the picture will appear to an observer in the theater. In order to obtain this information, we must consider the processes of perception, and if possible, transform our geometric forms from projected image space into perceptive space. In doing so, we will of course expect that no mathematical results will adequately account for the wide variety of differences found between individuals, and we must also expect that many important factors will be overly simplified or perhaps neglected entirely. Such an approach, however, has been found to give a formulation for setting the camera which is quite different from any obtained by using only the geometric image space, and under actual test conditions the results have adequately demonstrated the soundness of taking the perceptive space into consideration as adequately as has been possible.

An apparently reasonable, but nonetheless mistaken, assumption often made in establishing the theory of stereoscopic photography, is that in some manner binocular vision serves as a "range finding" device and thereby gives a good estimate of the actual distance to an object. Everyday experiences show, however, that if we have no information other than that given by stereopsis, or if the information we have is not in accord with previous experience, we can be badly fooled in our estimates of distance. Carefully conducted tests have adequately confirmed such experiences and have shown that we cannot make an accurate estimate of distance on the basis of stereopsis alone.

Charnwood[2] points out that no mechanism has been found in the extraocular muscles which would give information on the actual positions of the eyes essential for "range finding." He further shows that such "proprioception" would actually be a hindrance to binocular vision. Ogle[3] states that while "the phenomenon of stereopsis provides the most vivid and accurate *relative* depth discrimination, absolute localization probably results from a more complex psychic integration of empirical and stereoscopic stimuli." Luneburg[4] shows that as a result of experiments with an isolated point "binocular observation of a single point does not differ from monocular observation. Both are equally uncertain as to correlating a sensed point P to the physical coordinates of the stimulating point P^*." Charnwood[2] concludes after analyzing extensive data from many recent studies on the subject that "stereopsis has no scale and is capable

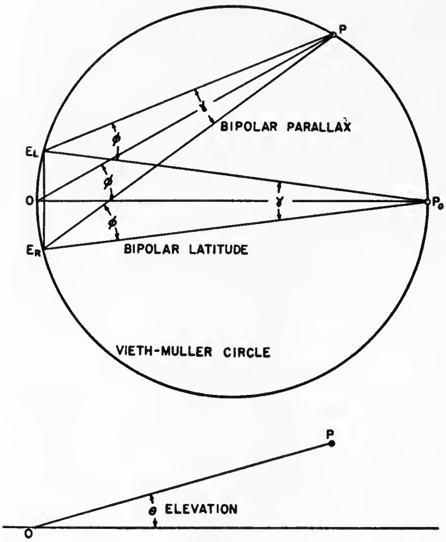


Fig. 3. Modified bipolar coordinates.

of many interpretations, the choice of interpretation being made in response to some outside factor."

Therefore there seems to be general agreement on two points: (1) stereopsis gives a very accurate *relative* depth discrimination, i.e., it will tell the observer which of two object points that are not too widely separated in space is the nearer; and (2) binocular vision cannot, of itself, give a reliable estimate of actual or absolute distance from an observer to an isolated object point. Incidentally, these are in agreement with other sensory perceptions, for in general it is found that while we can perceive *differences* in sensation, we have no direct sensation of absolute values.[5]

Mathematical Formulation — Modified Bipolar Coordinates

Mathematically, these experimental results indicate that we should use differential relationships in treating these problems of perception. Upon integration, we then have arbitrary constants corresponding to the indeterminate absolute values which seem to be inherent in the visual processes. These constants can then be evaluated upon the basis of experience or other empirical knowledge, just as we now evaluate them in constructing a perception from our sensory information.

It must be kept in mind, in treating problems of vision, that the eyes "see" only the angles between two object or image points, and all estimates of distances must be made in terms of these angles. Therefore a suitable coordinate system for relating points in the projected image space and the eyes of the observer should use angular values. The "modified bipolar coordinates" suggested by Luneburg[6] are well suited to this purpose and will be used here. Figure 3 shows these coordinates in terms of the "Vieth-Muller circle" through the observer's eyes. The *angle of elevation* (θ) gives the angle of the object point above a horizontal plane through the eyes. The *bipolar latitude* (ϕ) gives the angular displacement in the horizontal direction, or in other words the angular width. The *bipolar parallax* (γ) gives the displacement toward or away from the observer, and therefore indicates what we refer to as "depth." All three coordinates will have zero values for a point infinitely far away, on the horizontal plane through the eyes, and in the meridional plane.

The Basic Assumption

It seems reasonable to assume that the natural results in stereoscopic photography will be achieved when the dimensions, i.e. height, width and depth, of an object will appear to have the same proportion in the perception of the observer when he views the projected picture, as they would have had he viewed the object directly from the position where apparently the picture was taken. Unless the camera or projection lenses have bad distortion, the height and width will be maintained in proper proportion, so that the above assumption can be expressed in differential form in modified bipolar coordinates by the equation

$$\frac{d\gamma'}{d\phi'} = \frac{d\gamma}{d\phi_o} \quad (9)$$

where the primed values represent those for the observer in the theater and the unprimed values those for the same observer if at some position (O) from which the picture was apparently photographed. A more convenient form is obtained by rearrangement, giving:

$$\frac{d\gamma'}{d\gamma_o} = \frac{d\phi'}{d\phi_o} \quad (10)$$

Of course, if this equation holds, it means that only a small region in the projected image space will appear to have depth in proper proportion to width (or height). However it will be shown later that this equation can be integrated, following suitable geodesics in perceptive space, and the results of such integration indicate that proper proportions will be retained within practical tolerances throughout the entire picture area when the conditions expressed by Eqs. (9) or (10) hold.

Actually, except for a single viewing distance, the position from which the picture will appear to have been taken will not coincide with the actual camera position. For a given focal length of lens, therefore, there will be a single "normal" viewing distance, but at this distance *perspective and stereoscopic depth will be properly balanced.* With other focal lengths, or at other viewing positions, the observer will appear to occupy a position (O) shown in plan view in Fig. 4. Here let u represent a horizontal dimension near the object point A (which is not in the plane of convergence). The angle it subtends at the camera is ϕ, and at the apparent position of the observer is ϕ. The distances intercepted in the plane of convergence are w, and w_o, respectively. When projected, the distance w becomes w', and u will appear as u'. The angle subtended at the position of the observer in the theater by w' will be ϕ'. From Eq. (3) we have

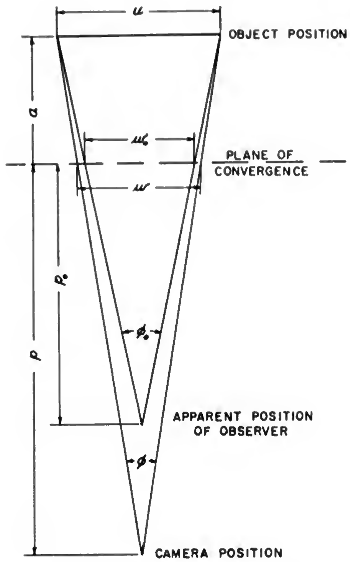


Fig. 4. Geometry for photography of an extended object.

$$w' = mw \quad (3)$$

and from similar triangles we see that

$$\frac{w_o}{u} = \frac{p_o}{p_o + a} \quad \text{and} \quad \frac{w}{u} = \frac{p}{p + a} \quad (11)$$

so that

$$\frac{w}{w_o} = \frac{p}{p_o}\,\frac{p_o + a}{p + a} \quad (12)$$

and

$$w' = mw_o\frac{p}{p_o}\,\frac{p_o + a}{p + a} \quad (13)$$

then, since $d\phi = dw_o/p_o$ and $d\phi' = dw'/v$, we have

$$\frac{d\phi'}{d\phi_o} = m\frac{p}{v}\,\frac{p_o + a}{p + a} \quad (14)$$

To obtain the relationships for the bipolar parallax angles, it is best to use the sketch given in Fig. 5. From this it can be seen that (since all angles are very small):

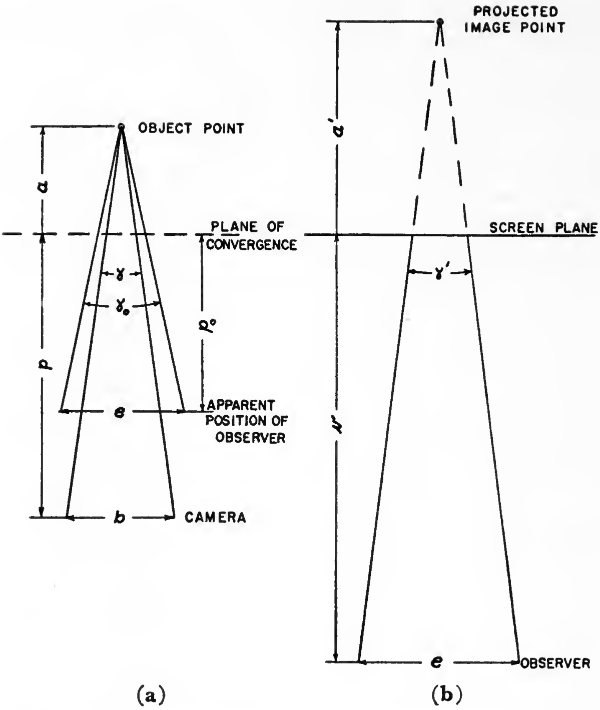


Fig. 5. Bipolar parallax in photography and viewing.

$$\gamma = \frac{b}{p + a}, \gamma_o = \frac{e}{p_o + a} \text{ and } \gamma' = \frac{e}{v + a'}, \quad (15)$$

Therefore

$$d\gamma' = -\frac{eda'}{(v + a')^2} \quad (16a)$$

$$d\gamma_o = -\frac{eda}{(p_o + a)^2} \quad (16b)$$

or

$$\frac{d\gamma'}{d\gamma_o} = \frac{(p_o + a)^2}{(v + a')^2}\frac{da'}{da} \quad (17)$$

Now from Eq. (5) we have

$$\frac{a'}{v + a'} = m\frac{b}{e}\frac{a}{p + a} \quad (18)$$

from which we obtain by differentiation

$$\frac{vda'}{(v + a')^2} = m\frac{b}{e}\frac{p\,da}{(p + a)^2} \quad (19)$$

giving

$$\frac{da'}{da} = m\frac{b}{e}\frac{p}{v}\frac{(v + a')^2}{(p + a)^2} \quad (20)$$

which, when substituted in equation (17) gives

$$\frac{d\gamma'}{d\gamma_o} = m\frac{b}{e}\frac{p}{v}\frac{(p_o + a)^2}{(p + a)^2} \quad (21)$$

Equating this to the right member of Eq. (14), we find that the condition for which Eq. (10) is valid is that

$$m\frac{p}{v}\frac{(p_o + a)}{(p + a)} = m\frac{p}{v}\frac{b}{e}\frac{(p_o + a)^2}{(p + a)^2} \quad (22)$$

or that

$$b = e\frac{(p + a)}{(p_o + a)} \quad (23)$$

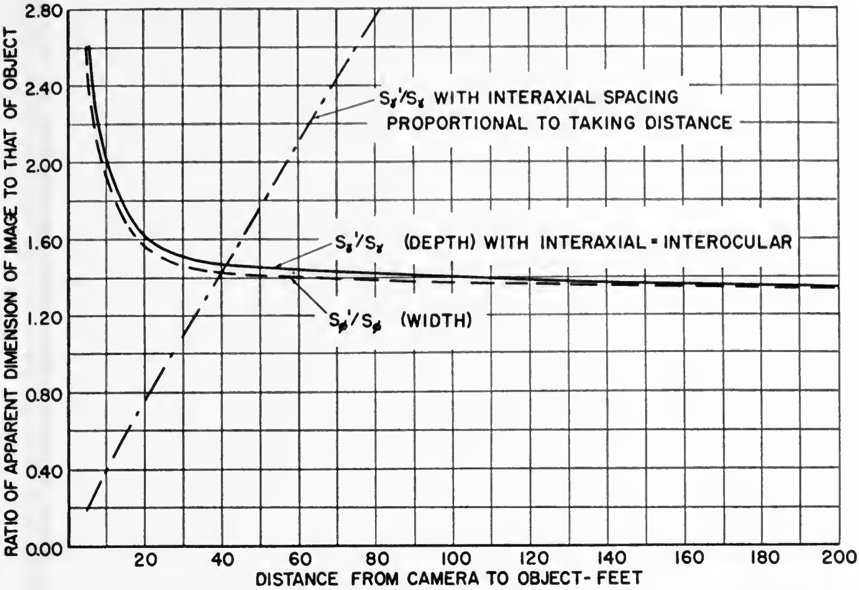


Fig. 6. Ratios of integrated apparent dimensions in projected image to corresponding apparent dimensions in object. These curves were calculated using equations (26) and (27) under the following assumed conditions: Viewing distance in theater is 40 ft. Screen width is 24 ft. Object has a depth of 3 ft and near edge is in plane of convergence at all camera distances. Focal length of camera lenses is 2 in. Interaxial spacing for solid curve is 2.5 in.

This is the fundamental equation for determining the interaxial spacing so that all dimensions will appear in natural proportion and that perspective and stereoscopic depth will be properly balanced. When conditions are such that the observer feels he is actually at the camera position — in other words, that $p = p_o$ — this equation simplifies to

$$b = e \qquad (24)$$

The correct interaxial spacing under these conditions is therefore the interocular distance or about 2.5 in.

Integration to Include Regions of Finite Size

The above derivation of course treats only with infinitesimally small regions in the picture. There is no assurance that the same conditions will hold over finite regions unless we can obtain an integral form of Eq. (10).

Fortunately, the geometry of perceptual space under conditions similar to those used in viewing motion pictures has been formulated by Luneburg,[6] and his equations provide a simple means by which this integration can be performed. He proposes as a suitable metric for this space

$$ds^2 = \text{csch}^2\sigma(\gamma + \mu)(\sigma^2 d^2\gamma + d\phi^2 + \cos^2 \phi d\theta^2) \qquad (25)$$

where the angles are those which have already been defined and σ and μ are constants which vary somewhat from individual to individual.

For simplicity we can use $\tau = \sigma(\gamma + \mu)$.

Apparent distance along any coordinate line, i.e. with only one variable

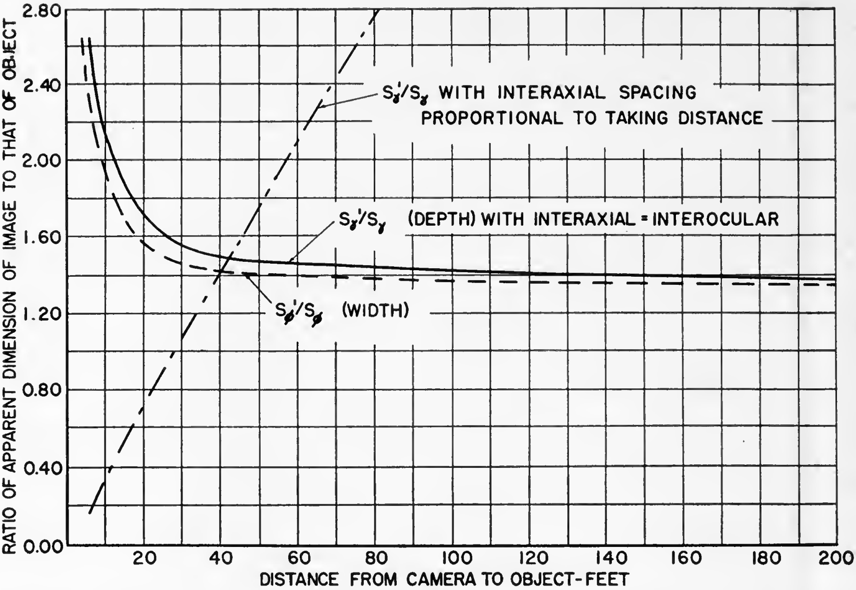


Fig. 7. Ratios of integrated apparent dimensions in projected image to corresponding apparent dimensions in object. These are calculated under the same assumed conditions as those in Fig. 6, except that the object is assumed to have a depth of 20 ft.

changing at a time, can be obtained by integrating Eq. (25), assuming the differentials of the unchanging coordinates as zero. Thus a change in apparent depth, s_γ, would be given by

$$s_\gamma = \int_{\tau_1}^{\tau_2} \operatorname{csch} \tau d\tau = \log_e \tanh (\tau_2/2) - \log_e \tanh (\tau_1/2) \quad (26)$$

Likewise an apparent width (angular) is given by

$$s_\phi = \operatorname{csch} \tau \int_{\phi_1}^{\phi_2} d\phi = (\phi_2 - \phi_1) \operatorname{csch} \tau \quad (27)$$

and apparent height (again angular) by

$$s_\theta = \operatorname{csch} \tau \cos \phi \int_{\theta_1}^{\theta_2} d\theta = (\theta_2 - \theta_1) \operatorname{csch} \tau \cos \phi \quad (28)$$

These distances are all given as angles, but as has been pointed out before, it is these very angles which the eyes use, and only through them can any estimate of actual distance be made. The condition, therefore, that apparent dimensions shall be in the same proportion as if the observer had been at the camera position will be given by the equations

$$s_\gamma'/s_\gamma = s_\phi'/s_\phi = s_\theta'/s_\theta \quad (29)$$

where the primed values represent those seen in the theater and the unprimed ones those which would have been observed at the camera position.

Actually, due to the forms of Eqs. (26) to (28), these cannot be exactly consistent. For example, Eq. (28) has a cos ϕ factor which does not appear in Eq. (27). This indicates that there will be a slight barrel distortion toward the edges of the field of view, and this may not be the same in the theater and before the camera when the other factors are selected for best balance. The error will be proportional to the *differences* in cosines of the angular field of view, however and within the range ordinarily used in

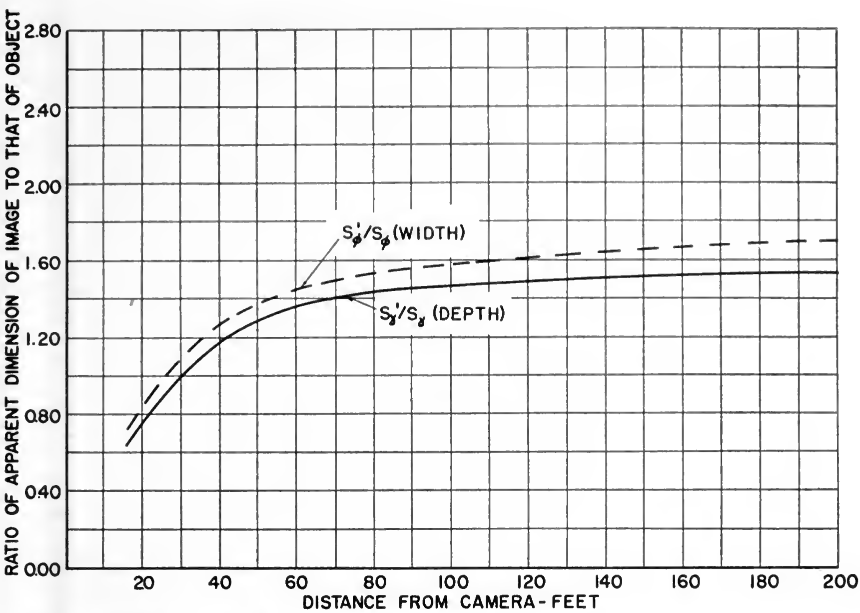


Fig. 8. Ratios of integrated apparent dimensions in projected image to corresponding apparent dimensions in object where the observer is apparently between the camera and the object. In these curves, the object depth is assumed to extend from the plane of convergence back to indicated distance from camera, and therefore varies with distance whereas in Figs. 6 and 7 it was assumed to be constant. Here the plane of convergence is assumed to be kept constant at 30 ft from the camera. Screen width is 24 ft, and viewing distance is 700 in. or 58.3 ft. Focal length of camera lenses is 3 in. and interaxial spacing is fixed at 3.5 in. This gives a picture which appears as if viewed from a point 20 ft in front of the plane of convergence.

motion-picture projection, this will probably never be serious.

If we assume therefore that the horizontal and vertical components s_ϕ, and s_θ, respectively, are proportional to each other, the condition that the depth will also be in proportion is that

$$s_\gamma'/s_\gamma = s_\phi'/s_\phi \qquad (30)$$

It is easiest to check this relationship by plotting these ratios for specific conditions, as has been done in Figs. 6 and 7. These plots show clearly that under the assumption that interaxial spacing is the same as the interocular distance, dimensional proportions will hold quite closely for all camera distances except those used for the largest close-ups. Of course these assume that lens focal lengths and viewing conditions are such that the observer feels that he is at the camera position. A more general case is shown in Fig. 8, where the apparent position of the observer is between the camera and the plane of convergence.

In order to compare the results of the above relationships with those based upon the assumption that the interaxial distance should vary with distance from camera to object, similar dimensional ratios for the latter assumption have been plotted in dashed lines in each of Figs. 6 and 7. The error in this assumption is immediately evident, for at only one distance (orthostereoscopic

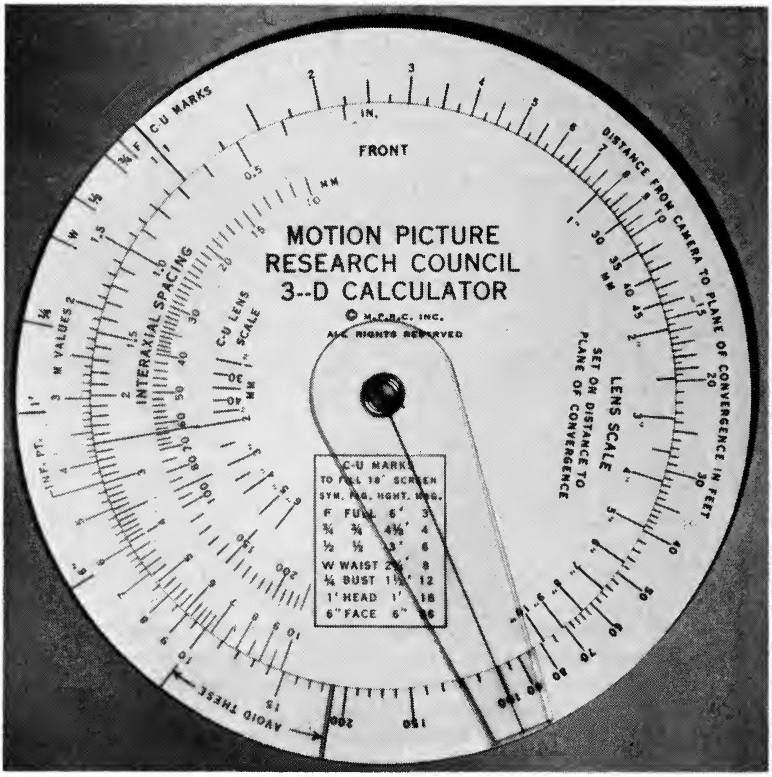


Fig. 9. The Motion Picture Research Council 3-D Calculator. This instrument, which is of white vinylite 4 in. in diameter, was designed in accordance with the principles set forth in this paper. It is now in use in the major motion-picture studios in Hollywood for the calculation of camera settings for their stereoscopic photography.

condition) are the dimensions in proper proportion.

The General Equation

A very important psychological factor has been disregarded in our discussion so far. We have long been accustomed to the use of the "close-up" in making figures on the screen appear to be very near. Most of the projected images are, of course, magnified, but these close-up views are actually "giantized." They have become so basic a part of the motion-picture convention, however, that we readily accept this giantization as normal.

When close-ups are to be photographed stereoscopically, this effect must be taken into account, and a correction made for this "giantizing." Since we unconsciously feel that we are looking at a figure much larger than normal, the correct interaxial spacing will be less than that normally used for medium shots. To allow for this, a "giantizing" factor G can be inserted in Eq. (23), giving the general equation

$$b = \frac{e}{G} \frac{(p + a)}{(p_o + a)} \tag{31}$$

Good judgment and experience must be

used in assuming the values for G, p_0/p, and a in this equation, and the selection will depend upon the kind of shot which is to be made. The ratio p_0/p will also, of course, depend upon the viewing distance and other conditions in the theater. Fortunately it has been found possible to make acceptable working assumptions for each of these values, so that satisfactory results can be obtained consistently. These have been used by the Research Council in the construction of a calculator illustrated in Fig. 9, which gives the best recommended settings for various lens focal lengths, camera distances and other conditions.

Practical Forms of General Equation

The selection of a suitable value for a depends on the "field of interest" in front of the camera. This is usually a more restricted area than the field of view, and its depth can often be given as a proportional part of the camera distance. For example, let us assume that the field of interest is centered beyond the plane of convergence at a distance from it of about half the camera distance. We can assume that a 2-in. focal length gives the best perspective relationship for the better viewing positions in an average theater. This means that $p_0/p = 2/f$ where f is in inches. Using $a = {}^1/_2\, p$ and $G = 1$, we find that Eq. (31) becomes

$$b = e\frac{3f}{4 + f} \qquad (32)$$

which is an excellent working equation for medium shots.

For telephoto shots, the depth a may be very small compared with the distances p and p_0. With these shots we want no giantizing effect so that $G = 1$. Therefore Eq. (31) becomes approximately

$$b = e(f/2) \qquad (33)$$

On the other hand, where the field of interest extends from the plane of convergence back to very distant backgrounds, the value of a will be very large compared with p or p_0. The factor $(p + a)/(p_0 + a)$ then becomes very nearly one, and (since again G is unity), the interaxial spacing is given by

$$b = e \qquad (34)$$

regardless of the focal length of the lens.

For close-ups, it is more satisfactory to specify the depth of the field of interest in terms of the height of the projected picture. This is the usual way of specifying the close-up; that is, it is a half-figure, bust or head, referring to the portion of the figure that fills the screen. The factor G is then also a function of the magnification and a simple expression for the interaxial spacing can be obtained. For example, assume that the depth of field of interest a is 5/6 of the picture height, h. Then for standard apertures 0.600 in. in height, $p = (h/0.6)f$, and since $p_0 = (2/f)p$, we find that $p_0 = h/0.3$. Substituting these values in Eq. (31) gives

$$b = \frac{f + 0.5}{G} \qquad (35)$$

as a very usable equation for close-up photography provided suitable values of the factor G are known. Incidentally, this equation approximates the values of Eq. (32) for medium shots closely enough for use with lenses having focal lengths of 3 in. or less. Results with it have verified its usefulness under the specified conditions.

The "giantizing" factor G in Eq. (35) is found to be a function of magnification only, and was evaluated on the basis of a series of actual tests. A plot of the results is given in Fig. 10.

Incidentally the factor G can be used for calculating shots which must deliberately be made to appear giantized or miniaturized. For example, if a scaled-down model with a scale factor of 8 is to be photographed to appear full sized, the factor G in Eq. (31) should be 8. On the other hand, if a model

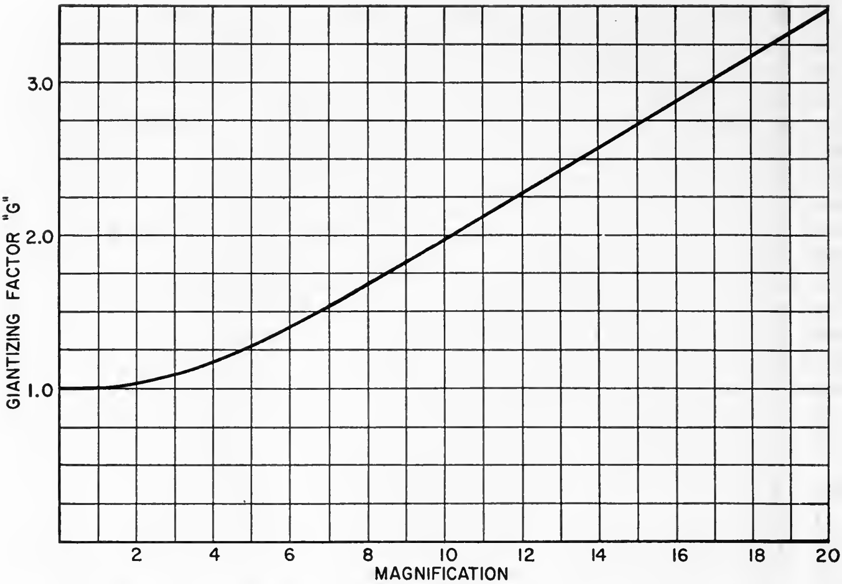


Fig. 10. Relationship between the giantizing factor "G" and magnification. The factor "G" is that required in equation (35), and the magnification is that defined by equation (3).

is to appear 1/3 actual size in the projected picture, G should be 1/3. Actually the problem is not quite as simple as this, for additional psychological factors, and "showman's license" must be taken into account. However, this formulation will provide a starting point from which tests can be made to determine the most satisfactory settings.

III. DETERMINATION OF FAR POINTS AND BACKGROUND DIVERGENCE

As mentioned previously, another natural assumption which has been made by many authorities in the field of stereoscopic projection is that the lines of sight must not diverge for any homologous point pairs. It is felt that such divergence would make them appear at a distance "beyond infinity," which of course could not happen. Fundamentally, this assumption is closely related to, and in fact is based on, the assumption that the eyes can in some way detect the absolute directions of these lines of sight. The Luneburg transformation (Eq. (25)), incidentally, handles such divergences, as long as they are quite small, without difficulty, indicating that perhaps fusion can take place and objects can be seen in correct proportion, even though the lines of sight do diverge slightly. Experience shows that this indication is correct. The eyes actually cannot detect slight divergences in the lines of sight, and while these are admittedly not encountered in natural seeing, nevertheless satisfactory fusion of images can take place if the amount of divergence is kept within reasonable limits.

Restrictions If No Divergence Is Allowed

Let us first consider the limitations

imposed upon the photography of stereoscopic pictures by the restriction that no divergence of the lines of sight to any homologous point pairs can take place in the viewing of projected pictures. This is equivalent to saying that no w' of the kind shown in Fig. 2 can exceed 2.5 in. or the normal interocular distance. From Eq. (3) then, this limits the corresponding value of w for objects infinitely far from the camera to not more than $2.5/m$. At an infinite distance, the lines of sight to the camera lenses will be parallel and therefore the maximum spacing of the lenses will be

$$b = e/m = \frac{W_{s}ep}{wpf} \quad (36)$$

which (except for the different notation) is the well known "*Wed/sf*" formula given by Rule,[7] Norling[8] and others.

Projection on theater screens requires the use of values of m of the order of 3 or more for most useful shots. This means that for screens 24 ft wide, interaxial spacings must be of the order of 3/4 in. or less. Such small spacings cannot be obtained with 35mm cameras without the use of beam-splitting devices, with their resultant loss of light. Furthermore, they give rise to "cardboarding" effects which are always undesirable.

How Much Divergence Can Be Tolerated?

Fortunately, it appears possible to allow some divergence of the lines of sight. Fry and Kent[9] have shown that stereo-acuity is fully as sharp with slight divergence as with an equivalent amount of convergence. In fact, clear single vision seems to be possible for most observers up to total divergence angles of greater than 5° (i.e., 2.5° for each eye). There is some evidence that eyes at rest apparently turn out approximately 1/2° each, indicating that there should be no physical discomfort even should the eyes turn outward to follow the diverging lines of sight. Finally, actual tests with pictures which have been projected so that a divergence in the lines of sight is required show that such pictures can be fused easily by most observers. They look perfectly natural, and no unusual strain is set up provided always that certain definitely specified limits are not exceeded.

On the basis of these considerations, the assumption has been made that a divergence of the lines of sight of 1/2° for each eye, or a total of 1° negative bipolar parallax could be allowed for an observer 40 ft in front of a screen 24 ft wide. Such a screen with standard aspect ratio, would be approximately 18 ft high. Since it can safely be assumed that no screen will ever be observed at a distance less than its height, a minimum viewing distance can be taken as 18 (or 20) ft. This will give a divergence of slightly over 1° for each eye which is still less than half of what can be safely tolerated by most observers.

The Maximum Separation Used in the Research Council System

On the basis of the above assumption, photography for a screen 24 ft wide should be such that no homologous point pairs are separated at the screen more than 480 × tan 1/2°, or 4.19 in. for each eye plus the interocular distance of 2.50 in. or a total of 10.88 in. The Research Council system therefore recommends a maximum separation of 11 in. for such point pairs.

This value will allow the photography of infinitely distant points with a "reduced" magnification value of 4.4, instead of 1.0 as allowed under the condition of no divergence. This in turn increases the maximum allowable value of b to 4.4 times the value given by Eq. (36). The manner in which this allows much more practical camera settings is shown in Table III.

Table III clearly shows the desirability, and in fact the necessity, of allowing a small amount of divergence. With the amount specified, it is seen

Table III. Comparisons of Camera Settings When No Divergence Is Used and When Slight Divergence Is Allowed.

Condition		Setting specified by Eq. (36)	Setting specified by Research Council
f = 2 in.	Distance to object (plane of convergence) is 10 ft. Interaxial	0.43 in.	1.9 in.
f = 3 in.	Waist figure close-up. Interaxial	0.29 in.	2.1 in.
f = 2 in.	Distance to plane of convergence is 10 ft. Distance from plane to farthest point in set (interaxial −2.5 in.) should not exceed	2 ft-1 in.	31 ft
Same but with interaxial spacing recommended in first line		6 ft-8 in.	Infinite
f = 2 in.	Distance from camera to plane of convergence if infinitely distant points are also in scene, using 2.5 in. interaxial	58 ft-4 in.	13 ft-3 in.

Table IV. Maximum Separation (in inches) of Homologous Point Pairs on Screens of Different Widths for Different Aspect Ratios.

Width of screen, ft	Screen magnification,* M_s	Aspect ratios (width/height)						
		4/3 (standard)	5/3	7/4	1.85/1	2/1	7/3	8/3
15	218	7.9	6.8	6.6	6.4	6.1	5.6	5.2
18	262	9.0	7.7	7.4	7.2	6.8	6.2	5.7
21	306	10.0	8.5	8.2	7.9	7.5	6.8	6.2
24	350	11.0	9.4	9.0	8.7	8.2	7.4	6.8
27	393	12.2	10.3	9.9	9.5	9.0	8.0	7.3
30	437	13.2	11.1	10.7	10.2	9.7	8.7	7.9
35	509	15.1	12.5	12.1	11.6	10.9	9.7	8.8
40	582	16.8	14.0	13.4	12.8	12.1	10.7	9.7
45	655	18.6	15.4	14.8	14.1	13.2	11.7	10.6
50	727	20.5	16.8	16.2	15.4	14.5	12.7	11.5

* This assumes that aperture has standard width.

that relationships between camera and set can be kept about as they now are for "flat" photography.

Photography For Wide Screens

When photography is for wider screens, care must be used that the divergence which has been specified is not exceeded. Assuming that no screens will be viewed from less than their height, and that at this minimum viewing distance the divergence of the lines of sight should not exceed 1° for each eye, Table IV gives the maximum separation of homologous point pairs for various screen widths and aspect ratios.

IV. DETERMINATION OF NEAR POINTS

At least three important factors must be given consideration when subject matter is made to appear between the screen and the observer. One of these, of course, is the "window" which forms the transition between the projected picture and the theater. Successful composition must take into account its effect in each of the three dimensions just as the effect of the masking or frame must be taken into consideration in "flat" pictures. A second factor can be termed "psychological" distortion, for it is caused by the recognition of relationships between the projected images and reference points in the theater and could be largely eliminated by projection in a perfectly dark, empty room. The third factor is the unnatural relationship which must exist between the convergence of the eyes and their "accommodation" or focus as they look at an image point which may be relatively near, yet must keep focused on the screen plane.

The Window

The stereoscopic window is provided by the limiting aperture of the stereo-transmission system. Since this is usually the masking at the screen, and this masking will provide the same aperture for both pictures, the window is usually at the screen plane. This is not necessary, however, for several more or less successful arrangements have been tried which project a "window in space" whose position is some distance in front of the screen. Such a positioning has several advantages as will be seen from the ensuing discussion.

With proper alignment of photographic and principal axes, the equivalent positions of the "window" in the object space will coincide at the plane of convergence when the window is formed by the projector apertures (or screen masking). This is shown in Fig. 11, which shows also the field of view of each of the two camera lenses, and of each eye of an observer standing in the position from which the picture apparently is taken (according to the perspective given by the lens focal length and viewing conditions).

It is at once apparent that the fields of view of the camera lenses and of the observer's eyes do not match. Therefore there will be a slightly unnatural effect near the edges of the picture. Vertical objects which appear in one of the two pictures but not in the other will be particularly confusing. The effect of such objects is even worse if they are supposed to be forescreen, as then by all conditions of natural vision they should be visible to both eyes.

The window, of course, will cut off any scenic elements which extend beyond it, even though such elements appear forewindow. In other words, if any scenic elements such as tree limbs, table tops or the like, extend out of the window, caution must be used that they are not cut off and left "dangling" in space over the heads of the audience.

Psychological Distortion

The photographic system discussed here is based upon the assumption that dimensional proportions will appear the same to an observer in the theater as if he had actually been in the position from which the picture appears to have been taken. In most cases therefore, he must be made to feel that he is actually nearer the scene than his distance from the screen. Unless he can do so, there will be a definite loss of "intimacy" and much of the dramatic effect otherwise possible from the presentation will be lost.

In order to make the observer feel that he is close to the scene, the geometric depth has been deliberately increased so that at screen distance the projected pictures will present the same "see-around" as the real objects

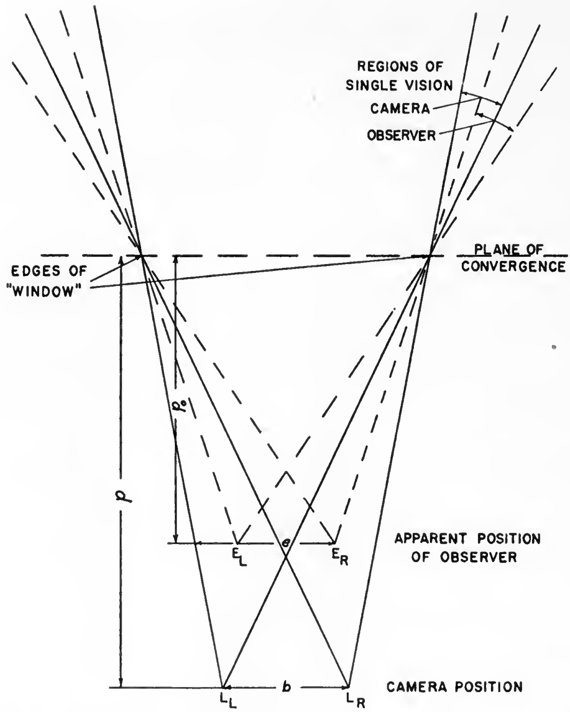


Fig. 11. Fields of view of camera and observer when window is at screen plane. As in all of these illustrations, angles must necessarily be greatly exaggerated.

would at much shorter viewing distances. The results are satisfactory, provided no clue is given as to the actual distances to the projected image points. When these points are behind the screen there is little likelihood that any external reference points can spoil the effect. However, as soon as they are brought forescreen, any objects which are visible in the theater may serve as reference points to give the observer a clue as to the actual distances to the projected images. For example, if the plane of convergence in a side view of an actor coincides with the side of his face, so that his shoulder and arm are forescreen, these may quite easily come out as far as halfway to the observer. Now if they do not come near the side of the screen or any other visible object in the theater, the effect will be quite acceptable. However, if it is noticed that, say, the front edge of the orchestra pit, or the lady with a big hat in the fifth row, are well beyond the closer portions of the image, the entire effect is lost and a definite "stretch" appears.

This effect is particularly noticeable in objects which are intended to come entirely forescreen. If they appear to do so, they will retain their natural proportions, but if for some reason they remain tied back to the screen plane, the distortion will be quite apparent. The reason we speak of this as "psychological" is therefore obvious, for it depends entirely upon the way the image positioning is interpreted by the observer.

The Accommodation-Convergence Relationship

The effects which have just been discussed will at worst cause the projected pictures to be unnatural in appearance and unpleasant to look at. The unnatural accommodation-convergence relationship required in the viewing of far forescreen image points, on the other hand, can cause real discomfort, and in extreme cases may result in pictures which the eyes will refuse to fuse — in other words, which will be seen as doubled.

In natural viewing, the accommodation is subconsciously adjusted to agree with the distance at which the eyes converge, at least for objects in the near and medium viewing distances. As far away as the screen for average viewing distances in the theater, however, changes in accommodation are very small even with large changes in convergence distance, so that little concern need be given this factor when images are at or behind the screen plane. On the other hand, when the image points are well forescreen, the eyes are required to converge on a relatively near point, yet maintain their focus on the distant screen. This means that the reflexive relationship between accommodation and convergence must be broken. Some observers can do this quite easily, others find it much harder, but generally speaking everyone must *learn* to look at forescreen objects in a manner quite different from that used in natural viewing.

It is not difficult for most observers to readjust this relationship as long as they can maintain fusion of the pictures. It does take a little effort, however, and this effort depends almost directly upon the amount of forescreen subject matter there is in proportion to that which is at, or behind the screen plane. It also increases rapidly as the proportional distance out from the screen increases.

Hofstetter[10] has shown that for most observers, fusion can take place with accommodation at distances comparable to those in an average theater, when image points are as close as 30 in. from the observer. Allowing a "factor of safety" of 2 as we did for the separation of background points, and again using a "close" viewing distance of 20 ft or 240 in., we find that most observers will be able to fuse stereoscopic pictures satisfactorily if they do not come closer than $\frac{3}{4}$ of the way out from the screen.

How Far Forescreen Can Image Points Come?

If there is so much difficulty with forescreen or forewindow subject matter, why bring image points forescreen at all? The answer is, of course, that only by doing so can the images be brought close enough to the observer to give the best effects obtainable with this medium. The "stage" between the screen and the observer is much nearer and therefore more "see-able" in many ways than that which extends back from the screen. Furthermore, forescreen subject matter comes out a proportionate distance to *each* observer, so that those in the back seats receive more of the effect — a partial compensation for their added distance from the screen.

On the other hand, most of the difficulties which have been mentioned can be controlled quite satisfactorily by observing a few simple rules, and by following the results of calculations based upon the theory which has already been developed.

For example, we have already seen that any subject matter which is to be viewed for any period of time, or with any clarity, should not come closer than $\frac{3}{4}$ or 0.75 of the way out from the screen. Actually the Research Council recommends use of an "0.8 near point" as the nearest any objects should be brought out. Even at this distance, viewing will be difficult and "stretch" will be apparent. Therefore for sustained pleasant viewing a closer limit is needed.

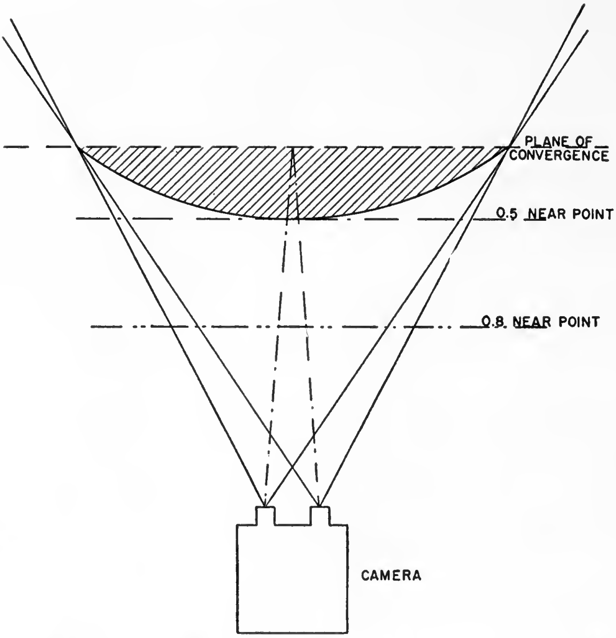


Fig. 12. Forescreen action area where window is at screen plane. Shaded area shows region in which forescreen action can take place without distortion or difficulties with the window edges. Some care must be given that forescreen subject matter near top at center is not cut off unnaturally.

Rule[7] recommended that no objects be brought closer than halfway from screen to observer, that is to the "0.5 near point." Experience has shown this to be a very sound recommendation, because within this limit psychological distortion seldom gives any trouble, and no noticeable strain occurs from accommodation-convergence breakdown. Under some conditions, with suitable subject matter, it is possible to have sustained, comfortable viewing at slightly greater ratios. This is particularly true if a forescreen window is used as discussed later. However, as a general recommendation, the 0.5 near point provides a safe limit which will insure satisfactory results.

Recommended Forescreen Action Areas

We now have the information needed to recommend suitable areas between the plane of convergence and the camera in which action can take place, or objects can be placed, and still give pleasing results when the pictures are projected on theater screens.

In the first place, we must avoid having forescreen, or rather forewindow subject matter near the sides of the picture. Except for the very near seats, the lower edge of the window seems to give but little trouble in this respect, and objects can be brought forward in the center of the scene without the distracting effects found at the sides. Attention must be given the top edge, however, for if it cuts off objects which should appear to project into the auditorium, the desired effect will certainly be lost.

When the screen masking forms the

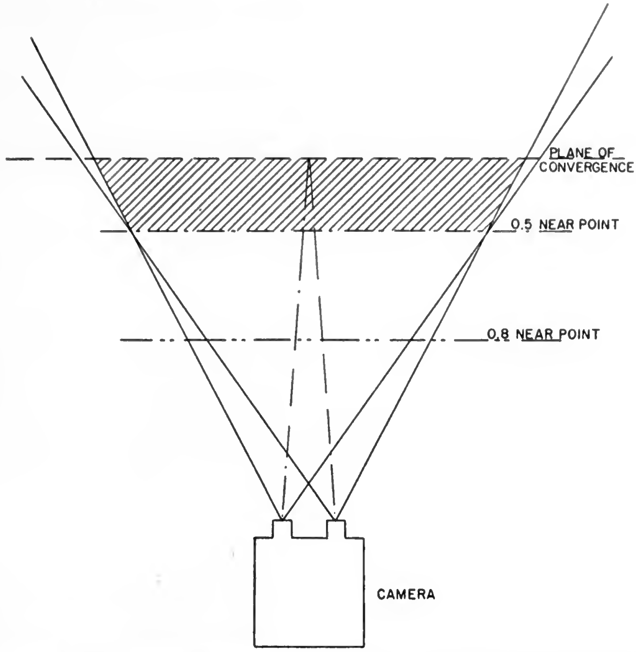


Fig. 13. Forescreen action area where a forescreen window is used at the 0.5 near point. Shaded area shows region in which forescreen action can take place without distortion and without difficulties with window edges.

window, the recommendation is that the main action in front of the camera be confined within a curved line as shown in Fig. 12, with the center at the 0.5 near point, and the sides arcing back to the plane of convergence at the edges of the field of view. Projected objects, and other subject matter, used to provide special effects, can be brought out to the 0.8 near point provided they are not held there for too long, and provided of course that the inevitable distortion will not be undesirable.

When a forescreen window can be used, the foreground action area can take the form shown in Fig. 13. There is some increase in this area over that shown in Fig. 12, but this may be lost by the decrease in aperture size, and therefore in field of view, required to provide the window.

Use of the "Near Point" Reference Lines

In brief then, it is desirable to establish on the set, two "near point" reference lines. One of these will be at those positions which will appear to be 0.5 of the way from the screen to each observer, and this will be the limit of any action or subject matter which is to be looked at for more than a few seconds at a time, or which is to be free from what we have termed psychological distortion. The other reference line should be at the 0.8 near point, and nothing which is to be seen clearly should be allowed to come closer to the camera than this reference line. If some special effect requires that objects do come closer than this, it must be remembered that they will be very hard to look at and for many observers will appear only as indistinct blurs.

V. CONCLUSIONS CONCERNING THE PRACTICABILITY OF THIS SYSTEM

(a) The system proposed by the Research Council is comparatively simple and straightforward. To one unacquainted with it, it may at first seem to be quite otherwise, but this is only because so many more factors can be taken into consideration and given proper treatment than can be treated in other systems.

(b) There is plenty of allowance for psychological factors and for judgment on the part of the operator. For example, the factor G is determined upon psychological principles. The best values to use for a and p_0 are a matter of judgment and experience. Nevertheless, once these factors have been determined properly, selection of a suitable interaxial distance is a simple, straightforward calculation.

(c) The system is flexible enough for use with any kind of shot. Intelligent treatment can be given close-ups, long telephoto shots, scenic vistas having great depth, and all the varied shots constantly occurring in everyday shooting. Provision is also made for taking good miniature shots and other special effects, and for suitably positioning titles, animated cartoons and similar subject matter which is to appear in three dimensions.

(d) The system has been proved in practice. Several critical tests have been made comparing this system with other proposed bases for calculating these settings. In each case the Research Council proposals were demonstrated as much superior in their ability to give pictures which were natural and pleasing to the eye and which avoided most of the difficult seeing conditions so often encountered in three-dimensional pictures.

This system therefore takes into account the basic principles of physiological optics, and uses these to establish the best way of taking stereoscopic pictures so that they will appear as natural as possible when projected in the theater and viewed from various viewing positions. In so doing, it uses principles which are known to give good results and which can be depended upon not to strain the eyes. Leading eye specialists have pointed out that the viewing of properly photographed three-dimensional pictures can actually be helpful to the eyes. We submit that pictures taken in accordance with the principles set forth here will have a maximum of third-dimensional effect, will have a pleasing balance between perspective and binocular depth, and will above all be easy and pleasing to look at.

References

1. Raymond Spottiswoode, N. L. Spottiswoode and Charles Smith, "Basic principles of the three-dimensional film," *Jour. SMPTE, 59:* 249–286, Oct. 1952.
2. Lord Charnwood, *An Essay on Binocular Vision*, Hatton Press Ltd., London, 1950.
3. Kenneth N. Ogle, *Researches in Binocular Vision*, W. B. Saunders Co., Philadelphia, 1950. Ch. 12.
4. Rudolph K. Luneburg, "The metric of binocular visual space," *J. Opt. Soc. Am., 40:* 627–642, Oct. 1950.
5. Walter C. Michels and Harry Helson, "Man as a meter," *Physics Today, 6:* 4–7, Aug. 1953.
6. Rudolph K. Luneburg, *Mathematical Analysis of Binocular Vision*, Princeton University Press, 1947.
7. John T. Rule, "The geometry of stereoscopic projection," *J. Opt. Soc. Am., 31:* 325–334, Apr. 1941.
8. John S. Norling, "The stereoscopic art," *Jour. SMPTE, 60:* 268–308, Mar. 1953.
9. G. A. Fry and P. R. Kent, "The effects of base-in and base-out prisms on stereo-acuity," *Am. J. Optom. Monograph, 4:* Dec. 1944.
10. H. W. Hofstetter, "Zone of clear single binocular vision," *Am. J. Optom. Monograph, 10:* Aug. 1945.

Optical Techniques for Fluid Flow

By NORMAN F. BARNES

In flow studies of liquids and gases, the velocity, pressure, density and temperature of the moving fluid can be obtained through the use of schlieren, shadowgraph and interferometer techniques. A basic optical and photographic description is given of the three systems, and a fundamental application comparison is made.

In the study of the flow of fluids, both liquids and gases, it is necessary to know the distribution of velocity, pressure, density or temperature of the moving fluid. In many cases it is possible to obtain much information by passing a beam of light through the flow and observing the effect of the fluid upon the light beam. The variations in density throughout the flow produce corresponding changes in the index of refraction of the fluid, these in turn causing variations in the beam of light. These latter variations can then be made visible on a screen or recorded on a photographic plate.

Though optical methods are sensitive only to density variations, the related flow characteristics of velocity, pressure and temperature can usually be calculated through the application of the laws of fluid mechanics, perhaps supplemented by certain nonoptical measurements to define the state of the fluid. There are three main advantages of an optical approach to the study of fluid flow: (1) the light will not distort or retard the flow; (2) measurements can be made over the entire field simultaneously; and (3) the measurements are free from inertia effects, such as are present if smoke or other particles are induced into the flow to make the characteristics of the latter visible. It becomes the object of the optical analysis, then, to analyze the variations imparted to the beam of light in order to find the corresponding changes in density of the fluid which produced such variations.

In Fig. 1, a light ray is shown entering a disturbing medium. After it emerges, it continues toward the screen, striking it at a point P′ rather than at the point P where it would have arrived had not the disturbance been present. The angle between the original direction of the light ray and its final direction after passing through the disturbance is represented by angle A. Since the velocity of light changes with the density of the medium in which it travels, the time of arrival of the ray at point P (time t) is different from the arrival time at point P′ (time t′). There are, therefore, three

Presented on October 8, 1952, at the Society's Convention at Washington, D.C., by Norman F. Barnes, General Electric Co., 1 River Rd., Schenectady 5, N.Y.
(This paper was received March 30, 1953.)

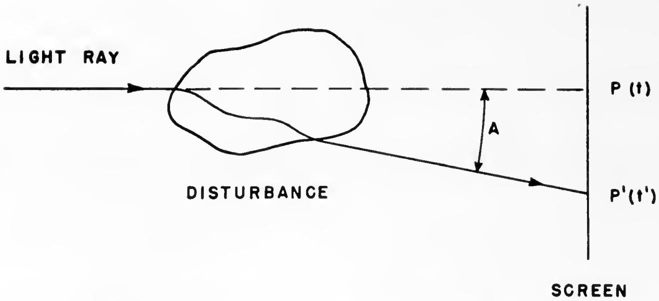


Fig. 1. Light ray entering a disturbing medium.

Fig. 2. Shadowgraph system.

variations or results of the disturbance which can be used as the basis of optical measurement. These are the displacement of point P to P′, the deflection or angle A and the difference in arrival time $t' - t$. Each of these three variations forms the basis of a different type of optical measurement. Thus, the shadowgraph method records the displacement of the ray while the schlieren method is based on the angular deflection of the ray. Finally, the interferometer method is based on the difference in arrival time between the disturbed and undisturbed rays. Each of these methods will be described, showing the type of equipment used and the nature of the results produced.

Figure 2 illustrates a shadowgraph system. A point source of light such as a spark gap illuminates a test area, the light then being allowed to fall upon a screen or photographic plate. If the rays of light do not undergo any deviation in the test area, the screen will be uniformly illuminated. However, if a disturbance is produced, the rays of light which are affected will undergo a deviation causing a corresponding change in the illumination on the screen. Thus, referring to Fig. 3, the rays which normally would have reached the screen at area A have been refracted to area B, producing a lowering of illumination at A and an increase at B.

Since the angular deviations of the rays are proportional to the first derivative of density perpendicular to the ray of light, and since the variation of illumination on the screen is proportional to the derivative of the deviation, the final variation of the light on the screen is proportional to the second derivative of the density in the disturbance. Consequently, the shadowgraph method is most useful in the study of abrupt variations in density such as those which occur in the presence of shock waves. For slow and continuous variations in density, the shadowgraph system becomes insensitive.

A spark gap, using either zinc or magnesium electrodes, has proved to be useful for shadowgraph photography. The primary reason for this is that the circuit characteristics for a spark discharge are such that they permit an extremely short time duration of the flash as compared with that produced by dis-

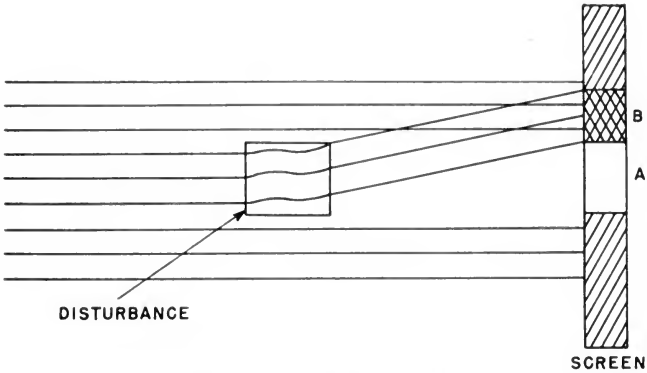


Fig. 3. Shadowgraph effect.

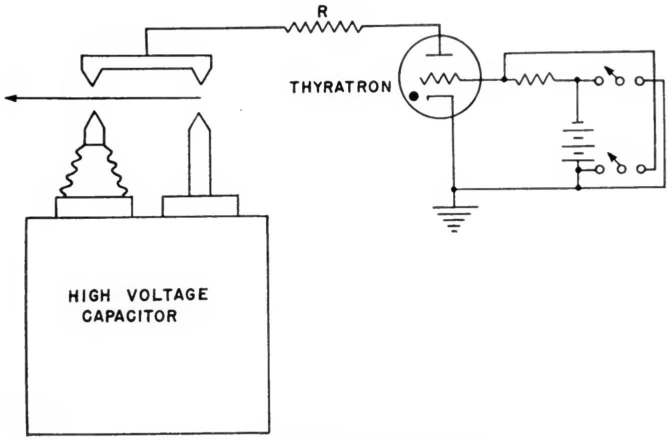


Fig. 4. Shadowgraph spark source.

charge lamps. By using the spark source shown in Fig. 4 effective photographic exposure times of 0.2 μsec have been made. That such an extremely short time could be obtained is due largely to keeping the inductance of the discharge circuit to an absolute minimum. Prior to the discharge the double-pointed electrode shown above the capacitor is allowed to "float" electrically, the gap separations being such that the high-voltage capacitor will not discharge itself. When the double-pole, double-throw switch is thrown, a positive voltage is applied to the thyratron tube so that it becomes conducting, therefore lowering the double-pointed electrode to ground potential. A spark then jumps from the high-voltage terminal to this electrode, thereby raising its potential to the maximum and thus allowing the spark to jump to the ground terminal on the capacitor. The two spark gaps are lined up in the direction of the arrow, producing the effect of a single source as seen from the disturbance. The entire discharge circuit consists of only several inches of heavy conductors.

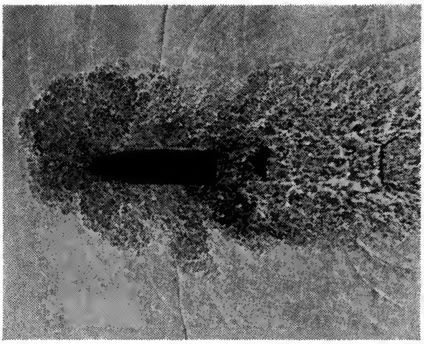


Fig. 5. Bullet discharged from the muzzle of a gun.

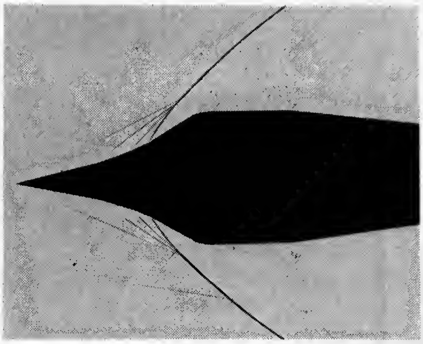


Fig. 6. Shadowgraph picture of supersonic flow past a multiple shock diffuser central body for a Mach number of 2.7

The results which have been obtained with the General Electric spark unit are illustrated in Fig. 5. Here the discharge energy was obtained from a 0.12 μf (microfarad), low inductance capacitor charged to 10,000 v. The picture shows a bullet being discharged from the muzzle of a gun. The many curved lines in the picture are sound waves generated when the compressed gases expand from the muzzle. The bullet is centered in the air that it pushes out of the barrel by its piston action. The expanding, turbulent gas behind the bullet gives it its acceleration.

The spark gap was placed approximately 15 ft to one side and perpendicular to the path of the bullet, while the film was placed at a distance of 18 in. to the other side and parallel to the bullet path.

Figure 6 shows a shadowgraph picture of supersonic flow past a multiple shock diffuser central body, for a Mach number of 2.7 as photographed by the NACA (National Advisory Committee on Aeronautics) laboratories.

Although the sensitivity of a shadowgraph system increases directly with the distance between the disturbance and the screen or photographic plate, a point is soon reached beyond which the resolution of the image rapidly deteriorates; thus, a compromise must be made between sensitivity and image quality. The size of the discharge spark will also have an important bearing upon the image quality of the shadowgraph picture. If a relatively large spark is used, it will have to be placed farther away from the disturbance in order to act effectively as a point source. Good results can be obtained using photographic films having moderate or high speeds. In general the extremely short exposure time produces a lower-than-normal contrast upon development so that it is advisable to use higher contrast developers with times ranging from normal to three times normal.

Figure 7 is an NACA shadowgraph picture of rather unusual interest showing the shock-wave formation on a P51 airplane in flight.[85] Figure 8 shows how this picture was produced using the parallel rays from the sun as the light source. The increasing strength of the shock wave going nearer to the upper surface of the airfoil acts as a prism to deflect the rays of light as shown.

While the great advantage of the shadowgraph method is the extremely simple arrangement which requires no lenses or mirrors, the system is far too insensitive for many applications. A small displacement which would be insignifi-

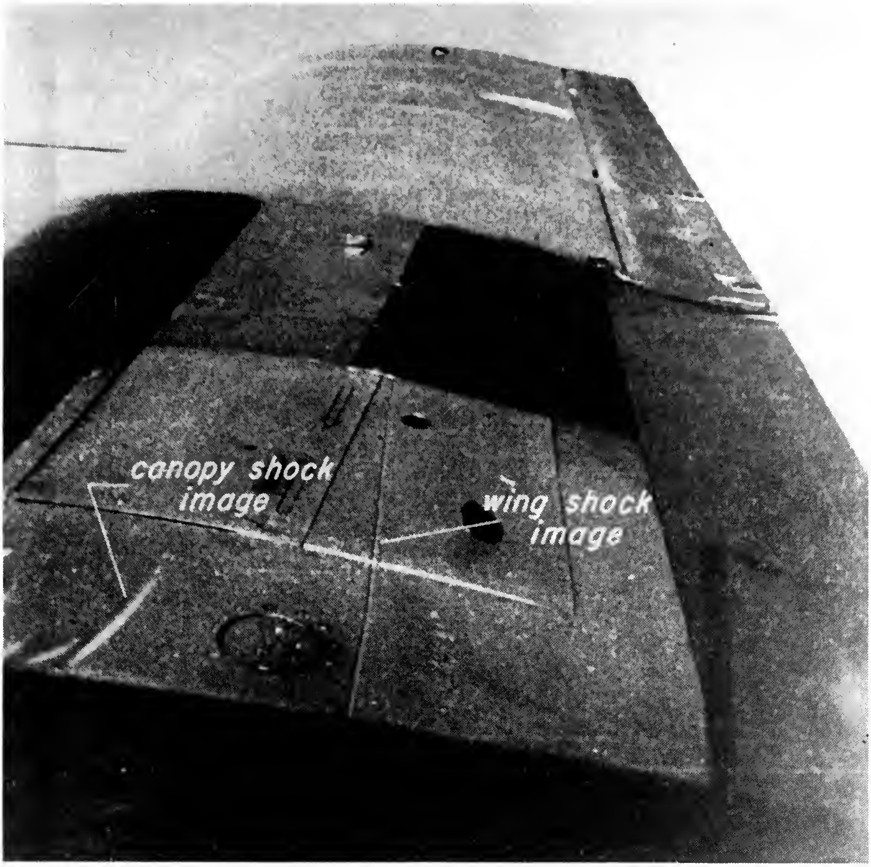


Fig. 7. Shadowgraph picture showing shock-wave formation on a P51 airplane in flight.

cant in a shadowgraph system could produce a very noticeable effect in a schlieren system. The operation of the schlieren method can best be described with reference to Fig. 9. Light from an illuminated pinhole or slit S is allowed to fall upon lens L1 and be converged to the image point at P. A lens L2 is used to focus upon the screen the striation or disturbances produced in the flow placed immediately to the right of lens L1. A knife edge E is moved laterally across the image point until all the rays passing through that image are obscured. The field as viewed upon the screen will then be uniformly dark. If a light ray in passing through the disturbance is refracted upward, this ray will no longer pass through the image point P but will travel above it. Hence this ray will not be obscured by the knife edge but will pass on to the screen, illuminating a point corresponding to the location of that particular part of the disturbance. Thus, for every point in the disturbance for which a similar refraction takes place, there will be a corresponding point illuminated on the viewing screen. The composite of all such points forms the image of the phenomenon to be investigated.

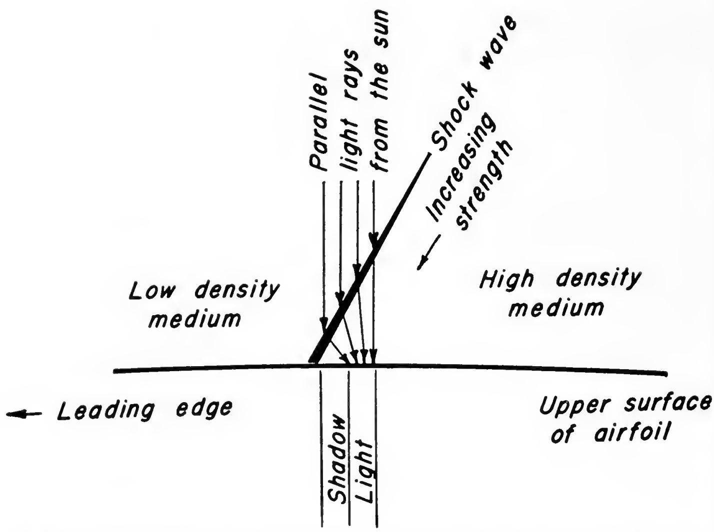


Fig. 8. Chordwise cross section showing production of a shock wave using parallel rays of the sun as a light source.

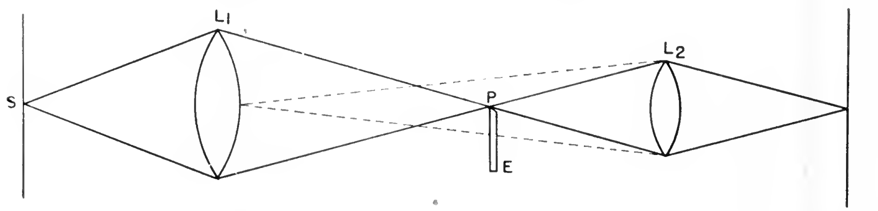


Fig. 9. Operation of the schlieren method.

If the bending in the disturbance is downward the rays will be caught by the knife edge, and the corresponding points on the viewing screen will be dark. In making the lateral adjustment of the knife edge when no disturbance is present, it is desirable to allow some of the rays to pass over the knife edge in order to produce a uniformly low background illumination. The presence of this background makes it possible to see more clearly in silhouette form the objects used in producing the air-flow phenomena. Thus, referring to Fig. 10, a downward deflection of rays darkens the screen while an upward deflection increases the screen illumination.

The field lenses used in the schlieren systems must be well corrected lenses, particularly from the standpoint of spherical aberration. Otherwise, it will not be possible to obtain a uniform brightness across the field projected upon the viewing screen. Also, if large amounts of chromatic aberration are present, the striation image on the viewing screen will not be sharp. The glass of the lenses must be of the finest optical quality and free from scratches so that the lenses will be striation free. Otherwise, any striae in the field lenses will be superimposed upon those which are being investigated.

If a large diameter field is required, it

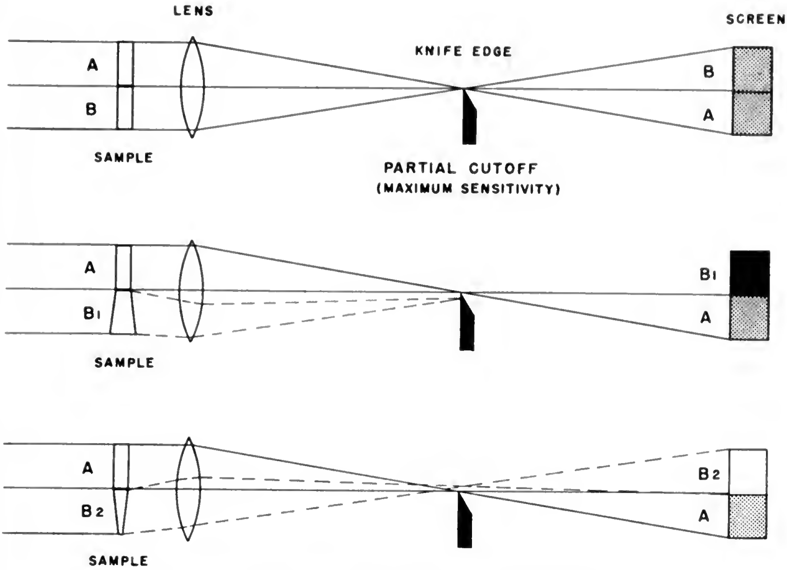


Fig. 10. Schlieren knife edge adjustment.

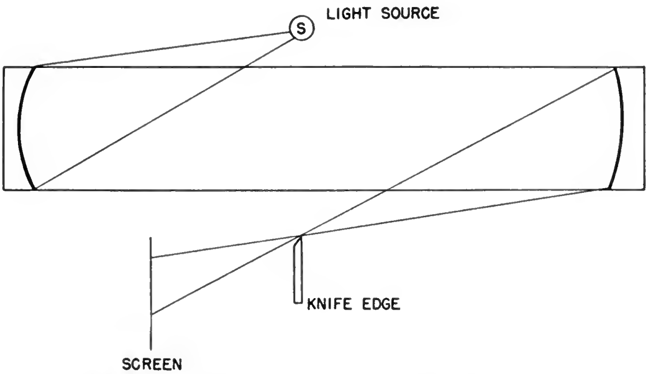


Fig. 11. Double concave mirror schlieren system.

is exceedingly difficult, if not practically impossible, to obtain well-corrected lenses. For that reason it is highly desirable to use concave mirrors in place of the lenses. The use of such mirrors has many advantages. Since first-surface mirrors are used, the optical quality of the glass does not affect the striation field. Furthermore, chromatic aberration is eliminated. Since the mirror surface can be parabolized, it is possible to obtain large mirrors which are well corrected for spherical aberration.

The double concave-mirror system shown in Fig. 11 has proved to be most satisfactory for a wide variety of applications.[178] Here the light passing through the investigation region has

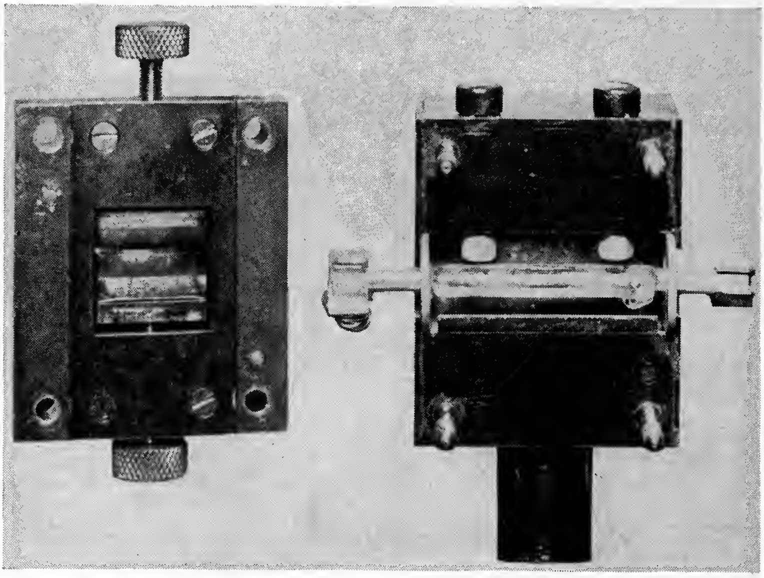


Fig. 12. Mazda Type B-H6 lamp with its air-cooling nozzle.

been made parallel by the first parabolic mirror. Since the sensitivity of the system is independent of the location of the disturbance between the two parabolic mirrors, one can simultaneously use the second parabolic mirror to focus the disturbance upon the screen as well as to converge the light to the source image point at the knife edge. However, because of aberrations of the system, a sharper image will be produced on the screen if a lens is used behind the knife edge for focusing purposes. In order that the system be effectively coma free, the light source and the knife edge must be on opposite sides of the common mirror axis. The equality of the angles from the source to the common mirror axis is required in order to avoid coma, while the size of the angles determines the amount of astigmatism which is introduced. Either of these aberrations will cause a poor knife-edge image of the light source, resulting in uneven sensitivity over the field.

One of the most useful light sources for schlieren systems is the Mazda Type B-H6 lamp. This is a 1000-w, high-pressure mercury lamp used with air cooling. A picture of this lamp along with its air-cooling nozzle is shown in Fig. 12. By the nature of the lamp itself this light source is a natural slit source whose dimensions are approximately 1 by 25 mm. For high sensitivity for photographic recording, slits as small as

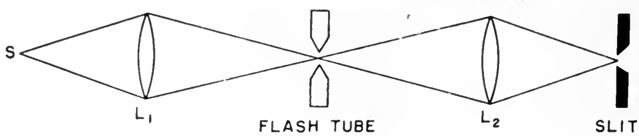


Fig. 13. Schlieren source.

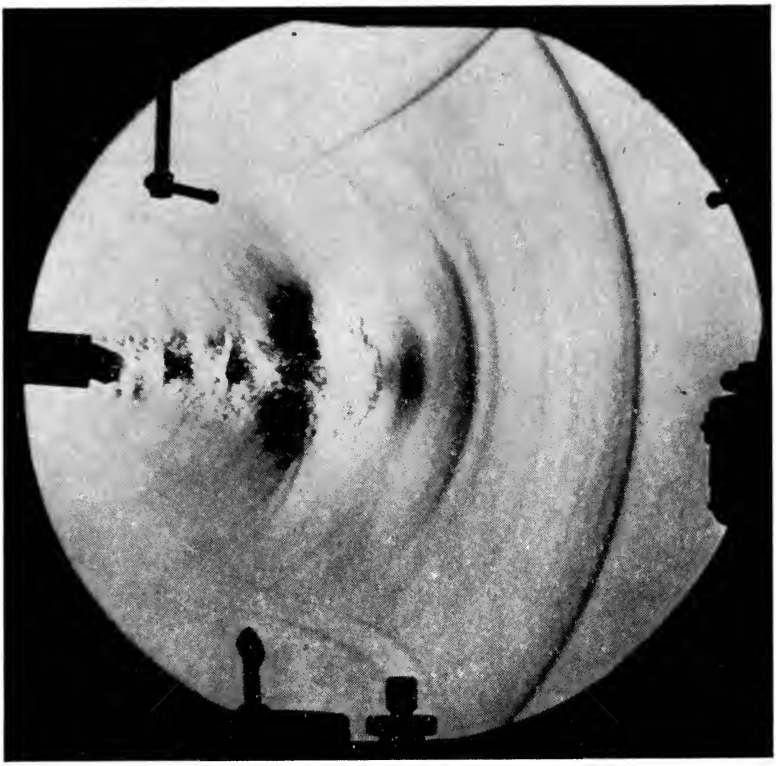


Fig. 14. Schlieren photograph of a jet showing sound waves and the reflection of one from a plate at the top, using a B-H6 lamp as a flash source.

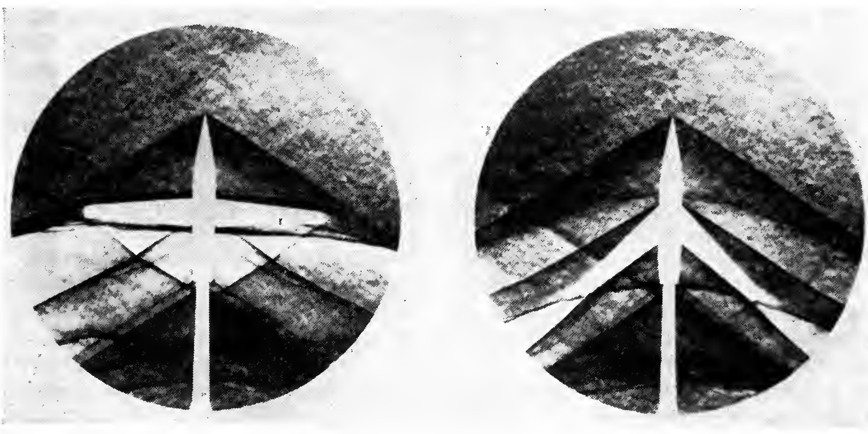


Fig. 15. Schlieren photograph of a jet with wings swept back at a rakish angle.

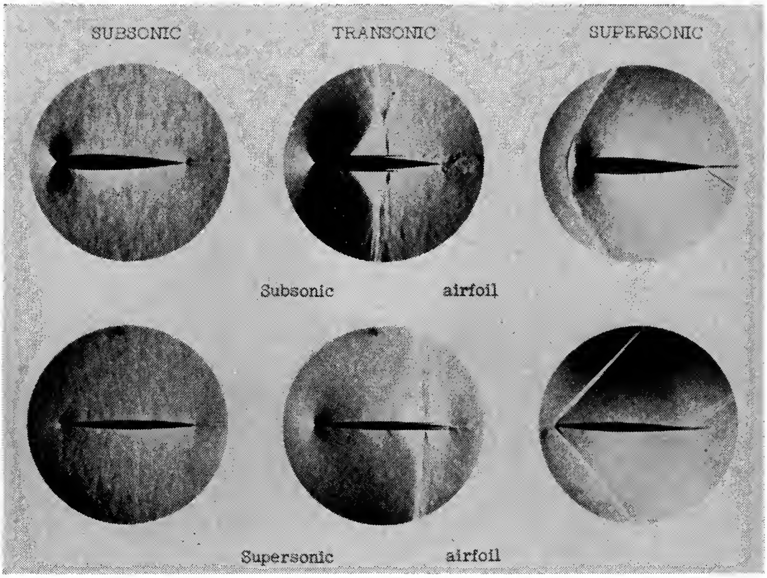


Fig. 16. Aerodynamic phenomena at subsonic, transonic and supersonic speeds for both subsonic and supersonic airfoil.

10 by 40 mils are placed in front of the light source.

The lamp can be operated continuously for visual observation or it can be flashed for taking instantaneous pictures effectively. When a 2-μf capacitor charged to 2000 v is discharged through the lamp, the effective photographic exposure time will be about 3 μsec.

A flashtube such as the FT 230 can also be used as the source of short-duration light. As shown in Fig. 13, light from the discharge gap is focused on a slit, which becomes the effective source for the schlieren system. For continuous observation and alignment purposes, a ribbon-filament, tungsten lamp is placed on the opposite side of the flashtube from the slit and is focused between the electrodes of the flashtube by an auxiliary lens. In this way any adjustment made with the tungsten lamp will be correct for the flashtube.

Figure 14 is a schlieren photograph of a jet, showing sound waves and the reflection of one from a plate at the top, using the B-H6 lamp as a flash source. Further illustration showing the application of schlieren techniques is seen in the NACA photographs of Figs. 15 and 16. The former points out the advantages that can be obtained by sweeping the wings of an airplane back at a rakish angle. With no sweepback, as in the picture at the left, a very intense shock wave is formed, represented by the black region immediately ahead of the wing. When the wing is swept back, the shock wave is also swept back with an accompanying reduction in intensity and hence a reduction in the wing drag. Figure 16 shows aerodynamic phenomena at subsonic, transonic and supersonic speeds for both subsonic and supersonic airfoil. It is interesting to note the tremendous disturbance produced in taking a subsonic airfoil through transonic region to supersonic speeds.

In a schlieren system the deviation of the rays, and hence the screen illumination, is proportional to the first derivative of the density variation. The sensitivity

Fig. 17. Shock wave and the explosive products which come from a dynamite cap.

of the system is proportional to the focal length of the mirrors in the system already described and inversely proportional to the width of the light-source image perpendicular to the knife edge. Optical aberrations, diffraction at the light-source image and the necessity for satisfactory image brightness impose limits upon the possible sensitivity.

High-speed photographic techniques have been developed for the study of transient phenomena in supersonic flow. Bradfield and Fish[56] have developed a repetitive spark light source capable of producing bursts of light for taking up to 250 schlieren photographs at a frequency as high as 16,000 pictures per second. With approximately 20-msec bursts of the high-speed sparks and effective exposure times of 2 to 4 μsec this technique has proved to be very useful in studying nonstationary supersonic flow problems.

A double-flash, high-speed photographic technique has been developed by Edgerton[187] for either the schlieren or shadowgraph study of transient shock waves or rapidly moving objects. Figure 17 shows the shock wave and the explosive products which come from a dynamite cap. The first flash from the spark unit was triggered by the light from the explosion, and the second flash was timed to occur approximately 4 μsec later during which time the shock wave traveled about 0.4 in., corresponding to an average velocity of 8,000 ft/sec. The exposure time is 0.2 μsec.

In the conventional schlieren system the density gradients at all points along the path of a light ray contribute to the resultant image. In a strictly two-dimensional flow no complications arise. However, from practical considerations the flow may be influenced by the boundary layer present on the glass walls as well as by waves reflecting from

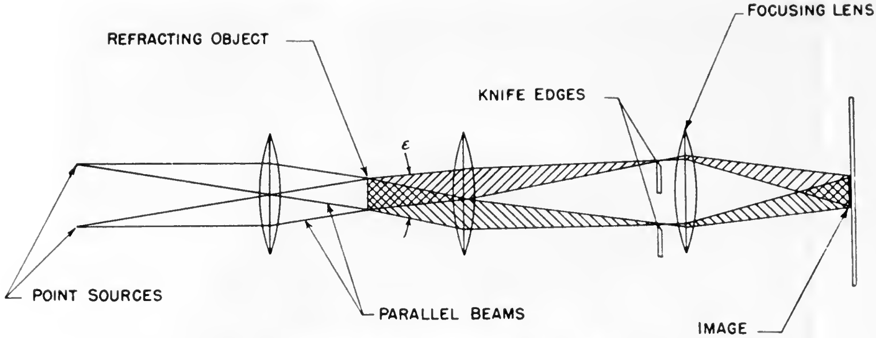


Fig. 18. Focusing effect with multiple sources.

these walls, so that the flow is actually three-dimensional. Consequently, one is forced to try to interpret three-dimensional flow with an apparatus which gives an integrated effect of such phenomena.

In order to obviate such difficulties Kantrowitz and Trimpi[63] have designed a schlieren system which can be focused at any plane in the test section. In order to be able to focus a system in this manner one must have either divergent or convergent light paths, since only by this means can the disturbances at various distances be singled out. Thus, referring to Fig. 18, if two sources and corresponding knife edges are used, the focusing lens will focus just the refracting object on the screen. Any other points will not be superimposed on the screen and will therefore be blurred. In actual practice, fifty or more slits are used along with their corresponding knife edges. Both the source-slit plate and the knife-edge plate are made photographically. Each of these sources and its corresponding knife edge acts as an individual schlieren system. Since the beams will only superimpose for a single plane of the disturbance, two-dimensional investigation of sections of a three-dimensional flow can actually be made. Burton[57, 58] has shown that the use of such grids of pinholes or lines permits the use of large optical fields which are not limited by the physical size of the lenses or mirrors used.

The use of schlieren technique becomes extremely difficult or even useless when the density of the flow is decreased to very low values. It has been shown that certain gases such as nitrogen are capable of emitting light for relatively long periods of time after they have been excited electrically. This phenomenon of persistence of luminescence is referred to as afterglow. Since the intensity of the afterglow increases with increased density of the glowing gas, a method is provided to make the flow disturbances produce their own light so that they may be photographed, the resulting picture being similar to a schlieren photograph in appearance. A schematic diagram of this afterglow equipment as developed by Williams and Benson[79] is shown in Fig. 19. Nitrogen from the supply tank is excited by means of high voltage and then drawn into the test chamber where its glow is photographed. Figure 20 shows the afterglow pattern over a 15°, double-wedge model at a stagnation pressure of 60 mm of mercury and an indicated Mach number of 2.6.

Recalling again the third type of optical measurement dealing with the difference in arrival time between a disturbed and an undisturbed ray, the change in the velocity of the light can easily be measured by comparing the beam of light which has passed through the test section with a similar beam which has passed through a stationary or

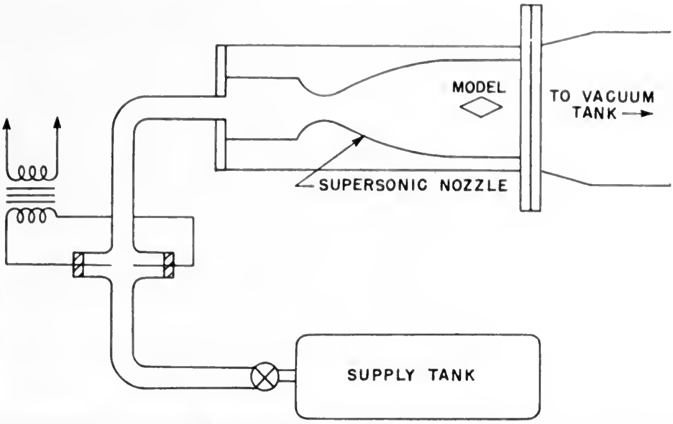


Fig. 19. Afterglow apparatus.

undisturbed field. Since light travels in a wave motion, these two beams of light can then be combined in such a way that the peaks of the waves of each alternately add and subtract to produce interference fringes or lines of alternately weak and strong intensity.

An interferometer consists essentially of a light source, a means of splitting the light into two beams, one of which passes through the test section, a means of recombining the two beams and a screen or camera for observing or recording the patterns. Thus, referring to Fig. 21, the light from the source is made into a beam of parallel rays by lens L1. When these rays reach the beam-splitting plate P1, part of the light is reflected to mirror M1. The part that is transmitted is directed through the test area by means of mirror M2. The two beams are then combined by means of the plate P2, those rays coming from M1 being partially transmitted by the plate and those

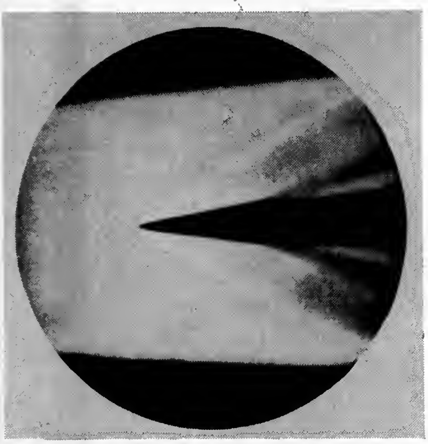


Fig. 20. Afterglow pattern over a 16° double-wedge model at a stagnation pressure of 60 mm of mercury and an indicated Mach number of 2.6.

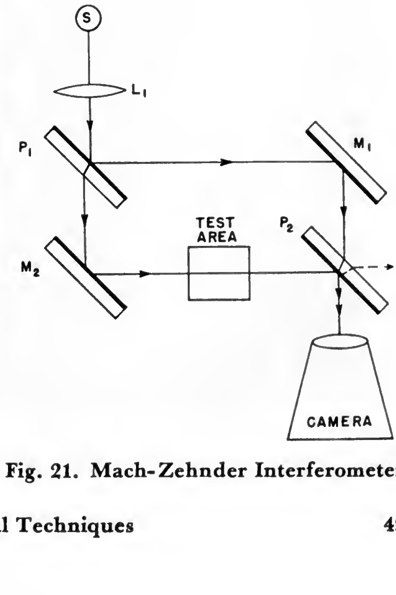


Fig. 21. Mach-Zehnder Interferometer.

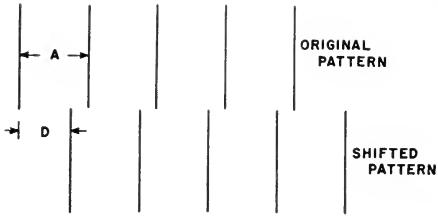


Fig. 22. Interference fringe shift.

coming from M2 being partially reflected. The camera lens then focuses the light upon the photographic plate.

If the optical components are essentially perfect and if the optical path lengths in the two halves of the system are identical over the entire field for no disturbance, then the field of view will be uniformly illuminated and the so-called infinite width fringe will be produced. If one of the beam-splitting plates or one of the mirrors is rotated slightly, interference fringes will be formed whose lines are equidistant and parallel to the axis of rotation of the mirror or plate. At each point where the optical paths in the two halves of the

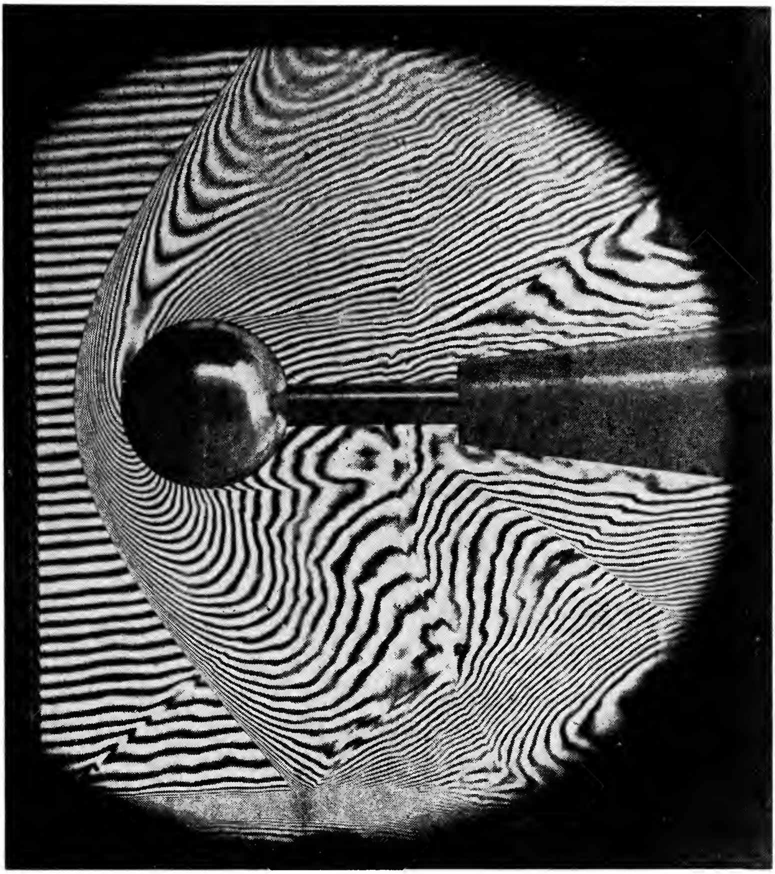


Fig. 23. Interferometer photograph of supersonic flow past a sphere in a free jet at Mach number 1.6.

system differ by an odd number of half-wavelengths of the light used, the two parts of this ray will cancel each other and thereby form a dark zone.

The outstanding characteristic of the interferometric method of analysis is its ability to provide quantitative data. Interference pictures can be evaluated to show the distribution of density throughout an entire flow field. Though the analysis of interference photographs of axially symmetric flow involves rather difficult integral equation calculations[124], the evaluation is relatively simple for two-dimensional flow. In this latter

Fig. 24. Flow past cascade of turbine blades.

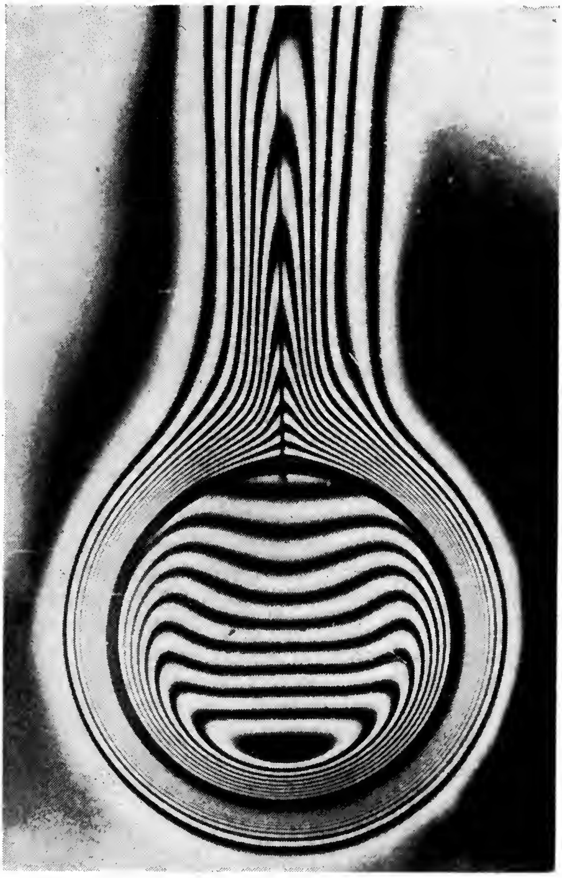


Fig. 25. Interference picture of temperature field formed by natural convection inside and outside a heated, hollow cylinder.

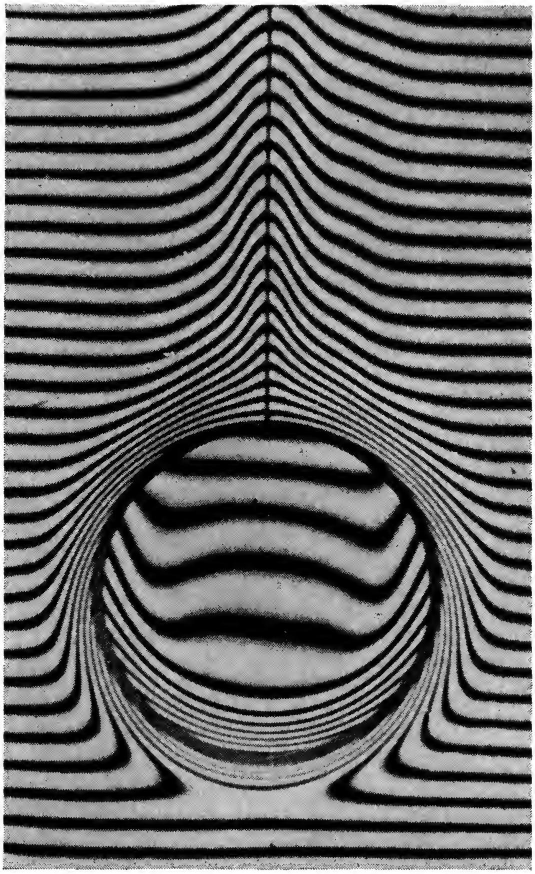


Fig. 26. Interferometer picture showing isothermal lines inside and outside a heated, hollow cylinder.

case, the change in density at a particular point in the flow is directly proportional to the fringe shift from the undisturbed pattern. Thus, referring to Fig. 22, let us assume an undisturbed pattern to have fringes separated by the distance A. If the disturbance then produces a shift D in the fringes, then the value of the corresponding changes in density can be computed so that it is possible to determine the density values throughout the entire field. The density change is directly proportional to the fringe shift D. Means of evaluating interferometer pictures are suggested by Ashkenas and Bryson[148].

Figure 23 is a NACA interference picture of the supersonic flow past a sphere in a free jet (Mach number 1.6). The undisturbed lines are shown at the left of the picture. In the right part of the picture the fringes are distorted by the varying retardation experienced by the light when traveling through the disturbance. Since the interferometer system is sensitive to infinitesimally small deviations of the light path, the method is particularly useful in relatively large regions of continuous and small variations in density. Where these variations are discontinuous or abrupt, interpretation of the picture becomes difficult. The most useful information is obtained when the interference fringes intersect the object surface at right angles. In order to accomplish this result the fringes can be oriented in any direction by proper rotation of the two beam-splitting plates and the two mirrors. An illustration of this, Fig. 24, shows the flow through a cascade of turbine blades.

Figure 25 shows an interference picture of the temperature field formed by natural convection inside and outside a heated, hollow cylinder. The displacement of the fringes can be interpreted, by calculation, in terms of air temperature. Thus the locus of the points of equal fringe shift will be an isothermal line. If, for the initial, undisturbed condition, the interferometer is adjusted for a single or infinite width fringe, each fringe in the resulting picture when the cylinder is heated represents an isothermal line itself as shown in Fig. 26. The change in temperature from one fringe to the next is approximately 2 C.

The outstanding advantages of the interferometric method of analysis are the extreme sensitivity which can be obtained and the relative ease of obtaining quantitative information. Together the shadowgraph, schlieren and interferometric techniques are playing an important part as a powerful tool in the study of high-speed, aerodynamic phenomena.

The author wishes to take this opportunity to express his sincere gratitude to Miss Leonore McAlonen and Mr. Frederick Thurston for their assistance in preparing the following bibliography. While a few of the earlier works in the fields listed are included in the bibliography, most of the literature referred to has been published in more recent times. Where an article refers to two or more of the three basic types of optical systems described or where an article describes a different type of system, such an article is listed under the heading of "General." The bibliography is by no means complete, and there are excellent references which could be added, many of which corresponding articles have a security classification. However, it is hoped that this bibliography as it is will be of valuable help to the many workers pioneering in this field.

BIBLIOGRAPHY

Schlieren Application

1. Allen, H. S., "The photography of sound waves and other disturbances," *Proc. Roy. Phil. Soc. (Glasgow)*, *33:* 71, 1902.
2. Barnes, G. M., "Supersonic wind tunnel laboratory at Aberdeen Proving Grounds," *Mech. Eng.*, *67:* 827, 1945.
3. Boelter, L. M. and Cherry, V. H., "Measurement of heat transfer by free convection from cylindrical bodies by schlieren method," *Heating, Piping and Air Conditioning*, *10:* 671, 1938.
4. Bogdonoff, S. M., "NACA cascade data for the blade design of high performance axial-flow compressors," *J. Aeronaut. Sci.*, *15:* 89, 1948.
5. Busemann, Adolf, "The drag problem at high supersonic speeds," *J. Aeronaut. Sci.*, *16:* 337, 1949.
6. Cranz, C. and Bames, E., "High-frequency schlieren cinematography and its use for investigating explosions and other rapidly occurring phenomena," *Z. Anal. Chem.*, *36:* 76, 1923.
7. Dhawan, S. and Roshko, A., "A flexible nozzle for a small supersonic wind tunnel," *J. Aeronaut. Sci.*, *18:* 253, 1951.
8. Feng, K. I., "Schlieren observation in the DVL high speed wind tunnel," *ATSC Rep.*, Apr. 1946.
9. Garside, Hall and Townend, "Flow states in emergent gas streams," *Nature*, *152:* 748, 1943.
10. Gawthrop, D. B., "Application of the Schlieren method of photography," *Rev. Sci. Instr.*, *2:* 522, 1931.
11. Gawthrop, D. B., "Propagation tests and the photography of the disturbance sent out by the explosion of commercial electric detonators," *J. Franklin Inst.*, *214:* 647, 1932.
12. Gothert, B., "High-speed measure-

ments on symmetrical bodies," *DVL Institut für Aerodynamik*, July 1944.
13. Hertzberg, A. and Kantrowitz, A., "Studies with an aerodynamically instrumented shock tube," *J. Appl. Phys., 21:* 874, 1950.
14. Hertzberg, A., "A shock tube method of generating hypersonic flow," *J. Aeronaut. Sci., 18:* 803, 1951.
15. "High speed motion picture photography," *Jour. SMPE, 53:* 440, 1949.
16. Humphrey, R. H. and Jane, R. S., "The observation of cataphoresis in colorless solutions," *Trans. Faraday Soc., 22:* 420, 1926.
17. Johnston, R. C., "Basic research in gas flow," *Tech. Eng. News:* 330, June 1948.
18. Klug, H., "Experimentelle Untersuchungen zur Schneidentonbildung," *Ann. d. Physik, 11:* 53, 1931.
19. Liepmann, H. W., "The interaction between boundary layer and shock waves in transonic flow," *J. Aeronaut. Sci., 13:* 623, 1946.
20. Liepmann, H. W. and Ashkenas, H. I., "Shock wave oscillations in wind tunnels," *J. Aeronaut. Sci., 14:* 295, 1947.
21. MacGregor, C. W., "The formation of localized slip layers in metals," *Metals and Alloys, 4:* 19, 1933.
22. Nadai, A., "Phenomenon of slip in plastic material," *Proc. Am. Soc. Test. Mat., 31:* 11–46, 1931.
23. Osterstrom, G. E., "Knocking combustion observed in a spark ignition engine with simultaneous direct and schlieren high-speed motion pictures and pressure records," *NACA U3835*, June 1948.
24. Payman, W., "The detonation wave in gaseous mixtures and the predetonation period," *Proc. Roy. Soc., A120:* 90, 1928.
25. Payman, W. and Robinson, H., "The pressure wave sent out by an explosive, Part I," *Safety in Mines Research Board Paper, No. 18,* 1926.
26. Payman, W. and Shepherd, W. C., "The pressure wave sent out by an explosive, Part II," *Safety in Mines Research Board Paper, No. 29,* 1926.
27. Payman, W. and Shepherd, W. C., "The disturbance produced by bursting diaphragms with compressed air," *Proc. Roy. Soc., A186:* 293, 1946.
28. Payman, W. and Titman, "The initiation of detonation in mixtures of ethylene and oxygen and of carbon monoxide and oxygen," *Proc. Roy. Soc., A152:* 418, 1935.
29. Payman, W. and Woodhead, D. B., "The wave speed camera and its application to the photography of bullets in flight," *Proc. Roy. Soc., 132:* 200–213 1931.
30. Pearce, R. B., "Supersonic tunnel for missiles," *Aviation Week, 49:* 22, Aug. 23, 1948.
31. Philpot, J. St. L., "Direct photography of ultracentrifuge sedimentation curves," *Nature, 141:* 283, 1938.
32. Prandtl, L., "Neue Untersuchungen über die strömende Bewegung der Gase und Dämpfe," *Physik. Z., 8:* 23, 1907.
33. Rothrock, A. M. and Spencer, R. C., *National Advisory Committee of Aeronautics 24th Annual Report*, 213, 1938.
34. Schrott, Carl, "Schlieren cinematography," *Die Kinotechnik, 12:* 40, 1930.
35. Shepherd, W. C., "The ignition of fire damp by explosives; a study of the process by schlieren methods," *Bur. Mines Bull.*, No. 354, 1932.
36. Stack, John, "The compressibility burble," *NACA TN543*, Oct. 1935.
37. Stack, John, "Compressible flows in aeronautics," *J. Aeronaut. Sci., 12:* 127, 1945.
38. "Supersonic wind tunnel," *Automotive Industries*, July 15, 1947.
39. Tawil, E. P., "Ultrasonic standing waves made visible in a gas by schlieren method," *Comptes Rendus, 191:* 92, 1930.
40. Tawil, E. P., "Observation methods for non-stationary sound waves," *Comptes Rendus, 191:* 998, 1930.
41. Tiselius, A., "A new apparatus for the electrophoretic analysis of colloidal mixtures," *Trans. Faraday Soc., 33:* 524, 1937.
42. Tiselius, A., "Schlieren method used to observe electrophoresis," *Trans. Faraday Soc., 33:* 524, 1937.
43. Tiselius, A., Pedersen and Eriksson-Quensel, "Observation of ultracentrifugal sedimentation by Toepler schlieren method," *Nature, 139:* 546, 1937.
44. Toepler, A., "Observations of the

singing flame by the schlieren apparatus," *Ann. d. Physik und Chemie., 128:* 126, 1866.

45. Toepler, A., "Optical studies by the schlieren method of observation," *Ann. d. Physik und Chemie., 131:* 33, 1867.

46. Toepler, M., "Neue einfache Versuchsanordnung zur bequemen subjektiven Sichtbarmachung von Funkenschallwellen nach der Schlierenmethode," *Ann. d. Physik, 27:* 1043, 1908.

47. Towend, H. C., "Statistical measurements of turbulence in the flow of air through a pipe," *Proc. Roy. Soc., A145:* 1934.

48. Townend, H. C., "A method of air flow cinematography capable of quantitative analysis," *J. Aeronaut. Sci., 3:* 343, 1936.

49. Townend, H. C., "Visual and photographic methods of studying boundary layer flow," *Aeronaut. Res. Comm. Great Brit. R & M*, #1803, 1937.

50. Turner, E. B., "Supersonic wind tunnel schlieren system," *Air Tech. Intelligence*, 35056.

51. Wood, R. W., "Photography of sound waves and the kinematographic demonstration of the evolutions of reflected wave fronts," *Phil. Mag., 50:* 148, 1900.

52. Wood, R. W., "On the propagation of cusped waves and their relation to the primary and secondary focal lines," *Phil. Mag., 52:* 589, 1901.

Schlieren Equipment

53. Bailey, D. Z., "Design and operation of schlieren system," *Gas Turbine Laboratory, M.I.T.*, unpublished report.

54. Barnes, N. F. and Bellinger, S. L., "Analyzing airflow," *G. E. Rev.*, Dec. 1944.

55. Barry, F. W. and Edelman, G. M., "An improved schlieren apparatus," *J. Aeronaut. Sci., 15:* 364, 1948.

56. Bradfield, W. S. and Fish, W. Y., "A high-speed schlieren technique for investigation of aerodynamic transients," *J. Aeronaut. Sci., 19:* 418, 1952.

57. Burton, Ralph A., "A modified schlieren apparatus for large areas of field," *J. Opt. Soc. Am., 39:* 907, 1949.

58. Burton, Ralph A., "Notes on the multiple source schlieren system," *J. Opt. Soc. Am., 41:* 858, 1951.

59. Fish, R. W. and Parnham, K., "Focussing schlieren systems," *Air Tech. Intelligence*, 101828, 1950.

60. Hartmann, Julius, "The acoustic air-jet generator," *Ingeniorvidenskabelige Skrifter* (Acad. Tech. Sci., Copenhagen), no. 4, 1939.

61. Herrington, R., "Design and construction of schlieren photography equipment," Rensselaer Polytechnic Institute, 1947.

62. Hett, J. H., "High speed stereoscopic schlieren system," *Jour. SMPTE, 56:* 214, 1951.

63. Kantrowitz, Arthur and Trimpi, R. L., "A sharp-focusing schlieren system," *J. Aeronaut. Sci., 17:* 311, 1950.

64. Liepmann, H. W., "The 2″ x 20″ transonic wind tunnel," *Final Report for Supplement Agreement*, No. 1 (S-4843) to Contract No. W 33-038 with A.T.S.C., Wright Field, 1945.

65. Mortensen, T. A., "An improved schlieren apparatus employing multiple slit-gratings," *Rev. Sci. Instr., 21:* 3, 1950.

66. Prescott, R. and Gayhart, E. L., "A method of correction of astigmatism in schlieren systems," *J. Aeronaut. Sci., 18:* 69, 1951.

67. Townend, H. C., "Improvements in the schlieren method of photography," *J. Sci. Instr., 11:* 184, 1934.

Schlieren Theory

68. Gayhart, E. L. and Prescott, R., "Interference phenomenon in the schlieren system," *J. Opt. Soc. Am., 39:* 546, 1949.

69. Lamla, E., "Über den Strahlengang bei Schlierenaufnahmen von einfachen ebenen Stosswellen," *Inst. f¨r Gasdynamik*, Oct. 1944.

70. *Report on the Second Conference of Fluid Dynamics* at Princeton, 1946, published by Navy Department, Bureau of Ordnance.

71. Rutkowski, J., "The schlieren method in flow observation of rarefied gases," *Air Tech. Intelligence*, 32955.

72. Schardin, H., "Das Toeplersche

Schlierenverfahren," *V.D.I. Forschungsheft* 367, Berlin 1934.
73. Schardin, H., "Toepler's schlieren method—basic principles for its use and quantitative evaluation," (translation of original paper) *Air Tech. Intelligence*, 22472.
74. Sevault, A., "Phenomenon of electric in supersonic nozzle," *Comptes Rendus* 225, #17, Oct. 27, 1947.
75. Shafer, H. J., "A physical optic analysis of the schlieren method," *Phys. Rev., 75:* 1313, 1949.
76. Straubel, R., "Dioptrik in Medien mit kontinuierlich variablem Brechungsindex," *Handbuch d. Physik, 6:* 485, 1906.
77. Taylor, H. G. and Waldran, J. M., "Improvements in the schlieren method," *J. Sci. Instr., 10:* 378, 1933.
78. Toepler, A., *Observation on a New Optical Beam*, Bonn, 1864.
79. Williams, T. W. and Benson, J. M., "Preliminary investigation of the use of afterglow for visualizing low-density compressibility flows," *NACA U3715*, Feb. 1949.
80. Wood, R. W., "Photography of sound waves by the schlieren method," *Phil. Mag., 48:* 218, 1899; *50:* 148, 1900.

Shadowgraph Photography

81. Barg, J., "Anyone can make photograms," *Am. Phot., 44:* 49, 1950.
82. Bull, G. V., "Investigation into the operating cycle of two-dimensional supersonic wind tunnel," *J. Aeronaut. Sci., 19:* 609, 1952.
83. Charters, A. C. and Thomas, R. N., "Spark photography of 9/16" diameter spheres," *J. Aeronaut. Sci., 12:* 468, 1945.
84. Clark, J. C., "Spark photographic techniques at the applied physics lab. at Tokyo Imperial University," Dec. 1945.
85. Cooper, G. E. and Rothert, G. A., Jr., "Visual observations of the shock wave," *NACA RM* No. A8C25, 1948.
86. Cranz, C., *Lehrbuch der Ballistik, 2,* 193; *3,* 271; Julius Springer, Berlin, 1926.
87. Cranz, C. and Glatzel, B., "Die Ausströmung von Gasen bei hohen Anfangsdrucken. I. Teil," *Ann. a. Physik, 43:* 1186, 1914.
88. Cranz, C. and Koch, R., "Über die explosionsartige Wirkung moderner Infanteriegeschosse," *Ann. d. Physik, 3:* 247, 1900.
89. Emden, R., "Über die Ausströmungserscheinungen permanenter Gase," *Ann. d. Physik, 69:* 264, 1899.
90. von Kármán, Theodore, "Supersonic aerodynamics—principles and applications," *J. Aeronaut. Sci., 14:* 373, 1947.
91. Keenan, P. C., "Shadowgraph method of determining the strength of a shock wave," *Phys. Rev., 69:* 677 1946.
92. Keenan, P. C. and Polachek, H., "Measurement of densities in Shock waves by the shadowgraph method," *NAVORD Rep.* 86-46.
93. Killing, V., "New techniques in photograms," *Am. Phot., 46:* 13, 1952.
94. Lafay, A., "Sur l'utilisation du procédé d'exploration à l'acetylène pour la mesure de la vitesse du vent et l'étude du champ aerodynamique," *Comptes Rendus, 152:* 694, 1911.
95. McMillen, J. H. and Harvey, E. N., "A spark shadowgraph study of body waves in water," *J. Appl. Phys., 17:* 541, 1946.
96. McMillen, J. H., Kramer, R. L. and Allmand, D. E., "Shadowgrams of spherical missiles entering water at supersonic speeds," *J. Appl. Phys., 21:* 1341, 1950.
97. Marlow, D. G. and Nisewanger, C. R., "Development of the spark shadowgraphs," *Air Tech. Intelligence*, 39131.
98. Scheyer, B., "Special effects with photograms," *Am. Phot., 43:* 506, 1949.
99. Schmidt, E., "Wärme und Kältetechnische Forschungen," *Z.V.D.I., 74:* 1487, 1930.
100. Stevens, V. I., "Hypersonic research facilities at Ames Aeronaut. Laboratory," *J. Appl. Phys., 21:* 1150, 1950.
101. Tanakadate, A., "Photographic study of air current produced by the movement of a screw propeller," *Comptes Rendus, 151:* 211, 1910.
102. Taylor, G. I. and Maccoll, J. W.,

"The air pressure on a cone moving at high speeds," *Proc. Roy. Soc., A139:* 298, 1933.

103. Townend, H. C., "Hot wire and spark shadowgraphs of the airflow through an air stream," *Phil. Mag., 14:* 700, 1932.

104. Wachsmuth, R., "Labialpfeifen und Lamellentöne," *Ann. d. Physik, 14:* 469, 1904.

Interferometric Application

105. Bennett, F. D., Carter, W. C. and Bergdolt, V. E., "Interferometric analysis of airflow about projectiles in free flight," *J. Appl. Phys., 23:* 453, 1952.

106. Berl, E., "Die Anwendung der Interferometrie in Wissenschaft und Technik," *Fortschritte der Chemie, Physik und Phys. Chemie., 19:* 7, 1928.

107. Bershader, D., "An interferometric study of supersonic channel flow," *Rev. Sci. Instr., 20:* 260, 1949.

108. Blue, R. E., "Interferometer corrections and measurements of laminar boundary layer in supersonic stream," *NACA TN* 2110, 1950.

109. Eckert, E. R. and Soehngen, E. E., "Studies on heat transfer in laminar free convection with the Zehnder-Mach interferometer," *USAAF TR*, No. 5747, Dec. 1948.

110. Gooderum, P. B., Wood, G. P. and Brevoort, M. J., "Investigation with an interferometer of the turbulent mixing of a free supersonic jet," *NACA TN* 1857, Apr. 1949.

111. Groth, E., "Evaluation of density fields around airfoils in wind tunnels by means of optical interference," *AVA Göttingen*, Film 211, May 1946.

112. Groth, E., "Evaluation of interferometer measurements on aerofoil in the 250 x 250 mm. high-speed tunnel," *Air Tech. Intelligence, 33:* 769.

113. Groth, E., "The evaluation of density field at high subsonic velocities by means of optical interference methods," *Air Tech. Intelligence*, 9888 Dec. 1943.

114. Groth, E., "Evaluation of density fields at high subsonic velocities by means of optical interference measurements," *N.A.A. Report N.A.*, 8783, Nov. 26, 1945.

115. Groth, E., "Measurement of flow around the airfoil by means of a Mach-Zehnder interferometer," Joint Intelligence Objectives Agency, Washington, BIGS-94, ADG 1011, Aug. 21, 1946.

116. Groth, E., "Sensitivity and accuracy of the interference method applied to pressure measurements in wind tunnels," *Air Tech. Intelligence*, 36783, *ADG* 1042.

117. Hansen, G., "Uber die Ausrichtung der Spiegel bei einem Interferometer nach Zehnder-Mach," *Z. Instrumententenk, 60:* 325, 1940.

118. Holden, J., "Shape of reflected interference fringes from interferometers coated with thin metal films," *J. Opt. Soc. Am., 41:* 504, 1951.

119. Hottenroth, "Über Einige Erfahrungen am Mach-Zehnderschen Interferometer," *Forschungs bericht* Nr. 1924, LFA, Braunschweig, Dec. 31, 1943 (Translated Air Doc. Div. T-2, Ame. Wright Field) *Air Tech. Intelligence*, 26635.

120. Hutton, S. P., "The use of interferometers in aerodynamics," TN No. Aero. 1808, *Royal Aircraft Establishment Report.*

121. Kennard, R. B., *Temperature Distribution and Heat Flux in Air by Interferometry; Temperature, Its Measurement and Control*, Reinhold Publishing Corporation, New York, 1941.

122. Ladenburg, R., "Interferometric analysis of supersonic jets," *NAVORD Report* 74-46.

123. Ladenburg, R., Panofsky, Van Voorhis, C. C. and Winckler, J., "Study of shock waves by interferometry," *NDRC Report* No. A 332 OSRD No. 5204.

124. Ladenburg, R., Van Voorhis, C. C. and Winckler, J., "Interferometric study of supersonic phenomena," *NAVORD Report* 69-46; *NAVORD Report* 93-46; *NAVORD Report* 7-47.

125. Laue, M., "Interference phenomena with plane parallel plates," *Ann. d. Physik, 13:* 163, 1903.

126. Laurence, J. C., "Interference method for obtaining the potential flow past an arbitrary cascade of airfoils," *NACA TN* 1252, 1947.

127. Liepmann, H. W. and Bryson, A. E.,

Jr., "Transonic flow past wedge sections," *J. Aeronaut. Sci. 17:* 745, 1950.

128. Mach, E., *Ann. d. Physik., 159:* 330, 1876.

129. Mach, E., "The interference of spherical waves," *Ann. d. Physik, 41:* 140, 1890.

130. Mach, E. and Gruss, *Wien. Ber., 78:* 467, 1879.

131. Mach, E. et alia, Various Papers, *Sitzungsber. d. Kais. Akad. d. Wissenschaften in Wien, 95:* 764, 1887; *98:* 41, 1303, 1889.

132. Mach, E. and Weltrubsky, J., "Über die Formen der Funkenwelle," *Wien. Ber., 78:* 551, 1878.

133. Matta, K. and Richardson, E. G., "Hot wire ultrasonic interferometer and its application to vapors," *J. Acoust. Soc. Am., 23:* 58, 1951.

134. Olsen, H. L., "An interferometric method of gas analysis," *Univ. of Wisconsin, CM*-514 NORD 9938, Nov. 1948.

135. Ostwatitoch, K., "The measurement of density in an airstream by means of the double-slit interferometer," *Air Tech. Intelligence*, 18 473.

136. Pack, D. C., "Investigation of the flow past finite wedges of 20 degree and 40 degree apex angle at subsonic and supersonic speeds using a Mach-Zehnder interferometer," *British R. & M.*, No. 2321, 1949.

137. Saunders, J. B., "An apparatus for photographing interference phenomena," *J. Research Nat. Bur. Standards, 35:* 157, 1945.

138. Schulz, L. G., "Interferometric method for accurate thickness measurements of thin evaporated films," *J. Opt. Soc. Am., 40:* 690, 1950.

139. Tolansky, S., *Multiple-Beam Interferometry of Surfaces and Films*, Clarendon Press, Oxford, 1948.

140. Tolansky, S., "New contributions to interferometry with applications to crystal studies," *J. Sci. Instr., 22:* 161, 1945.

141. Twyman, F., "Interferometers for the experimental study of optical systems from the point of view of the wave theory," *Phil. Mag., 35:* 49, 1918.

142. West, G. D., "An interferometer for sound waves," *J. Sci. Instr., 6:* 254, 1929.

143. Williams, W. E., *Applications of Interferometry*, John Wiley and Sons, New York, 1950.

144. Winckler, J., "The Mach Interferometer applied to studying an axially symmetric supersonic air jet," *Rev. Sci. Instr., 19:* 307, 1948.

145. Work, R. N., "A photoelectric recording interferometer for measurement of dimensional changes," *J. Research Nat. Bur. Standards, 47:* 80, 1951.

146. Zobel, T. W., "Flow Measurements by Light Interference," *Air Tech. Intelligence*, 26 165.

147. Von Vietinghoff-Scheel, K., "Laboratory report on the investigation of flow around two turbine blade profiles using the interferometer method," *NACA TM*, 1171, 1947.

Interferometric Equipment

148. Ashkenas, Harry I. and Bryson, Arthur E., "Design and performance of a simple interferometer for wind tunnel measurements," *J. Aeronaut. Sci., 18:* 82, 1951.

149. Bergdolt, V. E., "A new interferometer with a large working field," *Ballistics Res. Lab. Rep.* 692, 1949; also *Air Tech. Intelligence*, 61 168.

150. Candler, C., *Modern Interferometers*, Hilger & Watts Ltd., London, 1951, available from Jarrell-Ash Co., Boston.

151. DeFrate, L. A., Barry, F. W. and Bailey, D. Z., "A portable Mach-Zehnder interferometer," *Project Meteor Report No. 51*, Feb., 1950.

152. Eckert, E. R., Drake, R. M., Jr. and Soehngen, E. E., "Manufacture of a Zehnder-Mach interferometer," *USAAF TR* No. 5721, Aug., 1948.

153. Hansen, G., "Über ein Interferometer nach Zehnder-Mach," *Z. Tech. Physik., 12:* 436, 1931.

154. Kahl, G. D. and Bennett, F. D., "Experimental verification of source size theory for the Mach-Zehnder interferometer," *J. Applied Phys., 23:* 763, 1952.

155. Keating, T. J., "The Zehnder-Mach Interferometer," *Plane Facts*, 20-21, Oct. 1948.

156. Lamla, E., "Calibration of the Mach-Zehnder Interferometer," *Air Tech. Intelligence*, 38908.

157. Mach, L., "Über ein Interferenzrefraktometer," *Wien. Ber., 101:* 5, 1892; *102:* 1035, 1893.
158. Mach, L., "Über Einige Verbesserungen an Interferenzapparaten," *Wien. Ber., 107:* 851, 1898.
159. Peck, E. R., "A New Principle in Interferometer Design," *J. Opt. Soc. Am., 38:* 66, 1948.
160. Price, E. W., "Initial adjustment of the Mach-Zehnder interferometer," *Rev. Sci. Instr., 23:* 162, 1952.
161. Simmons, L. F. and Salter, C., "Interferometer for recording turbulent flow," *Aeronaut. Res. Comm. Great Brit. Rep.* 1454, 1932.
162. Waran, H. P., "New form of interferometer," *Proc. Roy. Soc. A 100:* 419, 1922.
163. Winckler, J., "A mechanical evaluation method for interferometer photographs," *Air Tech. Intelligence*, 1964.
164. Zehnder, "Ein Neuer Interferenzrefraktor," *Z. Instrumentenk, 11:* 275, 1891.
165. Zobel, T. W., "The development and construction of an interferometer for optical measurements of density fields," *NACA TN* No. 1184, also in *Air Tech. Intelligence* 22550.
166. Zobel, T. W., "Optical corrections for interference by a controllable deformation of the reflecting surfaces," *Air Tech. Intelligence* 31 053.

Interferometric Theory

167. Bennett, F. D., "Optimum source size for the Mach-Zehnder interferometer," *J. Appl. Phys., 22:* 184, 1951
168. Bennett, F. D. and Kahl, G. D., *Theory of Mach-Zehnder Interferometer* (to be published).
169. Clippinger, R. F., "Comparison between the Jamin-Mach interferometer and the Williams interferometer as applied to the study of airflow around a supersonic projectile of revolution," *Ballistics Research Lab. Report 567*, Aberdeen, Sept. 21, 1945.
170. Kennard, R. B., "An optical method for measuring temperature distribution and convective heat transfer," *J. Research Nat. Bur. Standards., 8:* 787, 1932.
171. Kinder, W., "Theorie des Mach-Zehnder Interferometers und Beschreibung eines Gerätes mit Einspiegeleinstellung," *Optik, 1:* 413, 1946.
172. Lamla, E., "Concerning the light path in a Mach-Zehnder interferometer," *Jahrbuch 1941 der Deutschen Luftfahrtforschung*, 727, Royal Aircraft Establishment Translation No. 80.
173. Peck, E. R., "Theory of the corner-cube interferometer," *J. Opt. Soc. Am., 38:* 1015, 1948.
174. Schardin, H., "Theorie und Anwendung des Mach-Zehnderschen Interferenz-Refraktometers," *J. Instrumentenk, 53:* 396, 424, 1933.
175. Weyl, F. J., "Numerical aspects o. quantitative interferometry," *Phys Rev., 69:* 677, 1946.
176. Winckler, E. H., "Analytical studies of the Mach-Zehnder interferometer," *N.O.L. Report*, 1077, Dec. 1949.

General

177. Adams, G. K., "A repetitive spark source for shadow and schlieren photography," *J. Sci. Instr., 28:* 379 1951.
178. Barnes, N. F. and Bellinger, S. L., "Schlieren and shadowgraph equipment for air flow analysis," *J. Opt. Soc. Am., 35:* 497, 1945.
179. Barry, F. W., Shapiro, A. H. and Neumann, E. P., "The interaction of shock waves with boundary layers on a flat surface," *J. Aeronaut. Sci., 18:* 229, 1951.
180. Beardsley, E. G., "The NACA photographic apparatus for studying fuel sprays from oil engine injection valves and test results from several researchers," *NACA Tech. Rep.*, 274, 1927.
181. Bleakney, W., Weimer, D. K. and Fletcher, C. H., "Shock tube; a facility for investigation in fluid mechanics research," *Rev. Sci. Instr., 20:* 807, 1949.
182. Brenholtz, G. E., "An investigation of methods of visual flow," *Air Tech. Intelligence*, 89619, 1950.
183. Brown, G. B., "On sensitive flames," *Phil. Mag., 13:* 161, 1932.
184. Brown, G. Burniston, "On vortex motion in gaseous jets and the origin

of their sensitivity to sound," *Proc. Phys. Soc., 47:* 703, 1935.
185. Buchele, D. R. and Day, P. B., "Interferometer with large working field utilizing schlieren optics," *NACA RM*, E50 I27, 1951.
186. Dernback, A. F., "Interference method of studying airflow as used at the LFA Research Center," May 1945.
187. Edgerton, H. E., "Double-flash microsecond silhouette photography," to be published in *Rev. Sci. Instr.*
188. Egerton and Gates, "On detonation of gaseous mixtures of acetylene and of pentane," *Proc. Roy. Soc., A114:* 137, 152, 1927.
189. Fage, A., "On the static pressure in fully developed turbulent flow," *Proc. Roy. Soc., 155:* 576, 1936.
190. Fage, A. and Townend, H. C., "An examination of turbulent flow with an ultramicroscope," *Proc. Roy. Soc., A135:* 656, 1932.
191. Fayolle, P. and Naslin, P., "Photographie instantanée et cinematographie ultra-rapide," *Editions de la Revue d'Optique*, Paris, 1950.
192. Ferri, Antonio, *Elements of Aerodynamics of Supersonic Flows*, Macmillan, New York, 1949.
193. Foucault, *Annales de l'Observatoire Imp. de Paris, 5:* 197, 1859.
194. Garby, L. C. and Nelson, W. C., "University of Michigan 8 x 13 inch intermittent-flow supersonic wind tunnel and appendix," *Air Tech. Intelligence*, 80958, June 1950.
195. Gawthrop, D. B., Shepherd, W. C. and St. Perrolt, G., "The photography of waves and vortices produced by the discharge of an explosive," *J. Franklin Inst., 211:* 67, 1931.
196. Jacobs, E. N., "Methods employed in America for experimental investigation of aerodynamic phenomena at high speeds," *NACA Misc. Paper #42*, Mar. 1936.
197. Jones, E., "Photographic study of detonation in solid explosives," *Proc. Roy. Soc., 120:* 603, 1928.
198. Kantrowitz, A. and Donaldson, C., "Preliminary investigation of supersonic diffusers," *NACA ACR* L5D20, 1945.
199. Ladenburg, R., Winckler, J. and Van Voorhis, C. C., "Interferometric studies of faster than sound phenomena," *Phys. Rev., 73:* 1359, 1948 and *Phys. Rev., 76:* 662, 1949.
200. Liepmann, H. W. and Puckett, A. E., *Introduction to Aerodynamics of Compressible Fluids*, John Wiley and Sons, New York, 1947.
201. MacColl, J., "The conical shock wave formed by a cone moving at high speeds," *Proc. Roy. Soc., 159:* 459, 1937.
202. Moore, A. D., "Further development of fluid mappers," *Elec. Eng., 70:* 396, 1951.
203. *National Physical Laboratory Annual Report for 1932.*
204. "Kinematography of air flow," *National Physical Laboratory Annual Report for 1933.*
205. Nelson, R. A., "Free convection of heat in liquids," *Phys. Rev., 23:* 94, 1924.
206. Nicholson, H. M. and Field, J. P., "Some experimental techniques for the investigation of the mechanism of flame stabilization in the wakes of bluff bodies," *NOrd*, 7386, Johns Hopkins University, Dec. 1948.
207. Pugh, E. M., Heine-Geldern, R., Foner, S. and Mutschler, E. C., "Glass cracking caused by high photography," *J. Appl. Phys., 23:* 48, 1952.
208. Smith, L. G., "Photographic investigation of the reflection of plane shocks in air," *Phys. Rev., 69:* 678, 1946.
209. Strong, J., *Procedures in Experimental Physics*, Prentice-Hall, New York, 1938.
210. *Symposium on Wind Tunnel Optics, Air Tech. Intelligence*, 82 325.
211. Taylor, G. I. and MacColl, J., "Air pressure on a cone moving at high speeds," *Proc. Roy. Soc., 139:* 278, 298, 1933.
212. Taylor, M. K., "A balsa-dust technique for air-flow visualization and its application to flow through model helicopter rotors in stator thrust," *NACA TN* 2220, 1950.
213. Tietjens, O., Wien, W. and Harms, J. *Handbuch der Experimental Physik I:* 695, Leipzig, 1931.
214. Tilton, L. W., "Optical glass of interferometer and schlieren quality for wind tunnel optics," *J. Research Nat. Bur. Standards, 42:* 279, 1949.

215. Tremblot, R., "Sur l'étude des courants gazeaux au moyen des interférences," *Comptes Rendus, 192:* 480, 1931.
216. Tremblot, R., "Sur l'application des interférences à quelques problèmes d'écoulement à grandes vitesses," *Comptes Rendus, 193:* 418, 1931.
217. Von der Heyden, E., Jr., "The design of schlieren and shadowgraph apparatus for the proposed wind tunnel at R.P.I.," *Air Tech. Intelligence*, 66990, June 1949.
218. Weyl, F. J., "Analytical methods in the optical examination of supersonic flow," *NAVORD Rep. 211-45*, Dec. 1945.
219. Williams, T. W. and Benson, J. M., "Preliminary investigation of the use of afterglow for visualizing low-density compressible flows," *NACA TN* 1900, 1949.

Conversion of 16mm Single-Head Continuous Printers for Simultaneous Printing of Picture and Sound on Single-System Negative

By VICTOR E. PATTERSON

The big rush for television news release prints from single-system negative prompted the design of this conversion unit. In news work every possible shortcut must be taken, without lowering the quality of the release prints. These converted printers cut the printing time in half; also, they save considerable raw stock, because in loop printing a splice may give way and create a synchronization problem in resplicing the negative, with the result that stock with sound printed but no picture usually has to be discarded. No loss occurs when picture and sound are printed simultaneously on these printers.

In November of 1951, McGeary-Smith Laboratories of Washington, D.C., requested a unit to attach to one of their Bell & Howell Model J printers to print single-system sound and picture at one time in order to speed up the printing of television news film. The unit described in this article was made and attached to one printer. It worked so efficiently and saved so much valuable time that a second printer was promptly converted.

These units make it possible for prints to be taken off the processing machines in 30 to 40 min after negative is received for timing and printing. Also, by using negative on a loop tree for continuous printing, one printer running at 90 fpm can keep a processing machine going at 80 fpm. This conversion may prove of interest and value to laboratories doing television news work.

Although it does not save time on double-system sound, the printer remains available for this work simply by turning off the lamp not needed at the time. In case of printer trouble this unit may be quickly removed and installed on another printer, as no drilling or tapping is done on the printer casting; instead existing screw holes are used. As a result of the design of the attachment the printer may be restored to its original design by merely removing the attachment and replacing the single-head printer parts.

Figure 1 shows the parts needed for this conversion, consisting essentially of a prism made of plexiglas or optical glass (the one used here is optical glass). The prism has a tongue cut on its face which extends into the printing aperture

A contribution submitted August 5, 1953, by Victor E. Patterson, Telex Films, 5805 44th Ave., Hyattsville, Md.

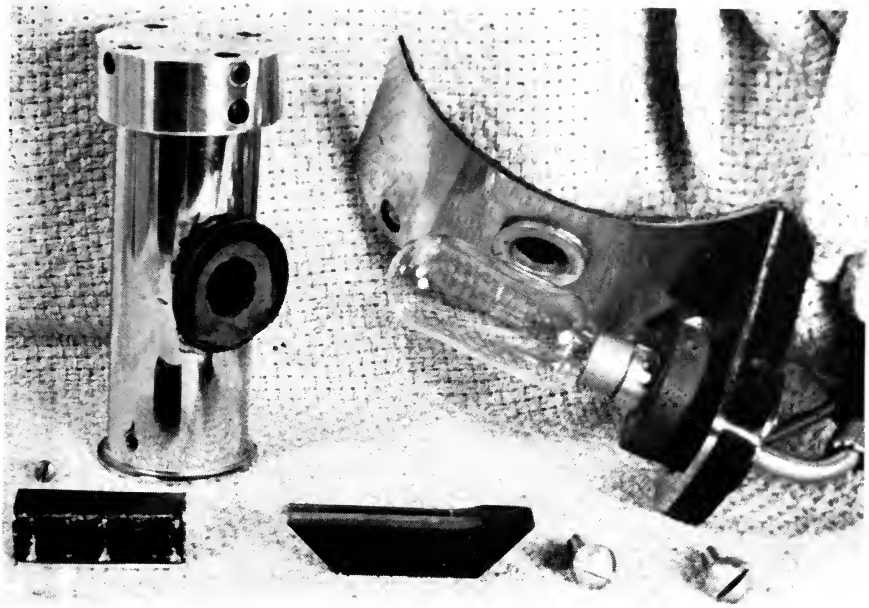


Fig. 1. Parts used in conversion.

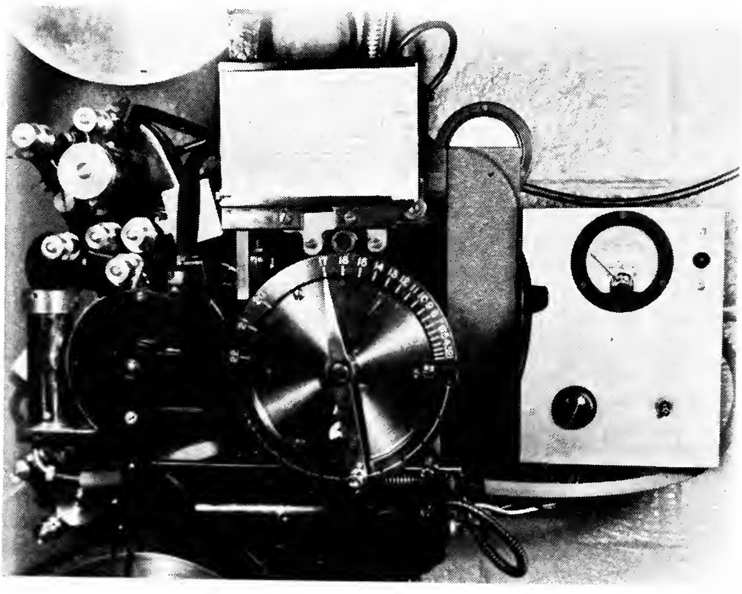


Fig. 2. Model J printer with unit attached to aperture housing. Electrical circuit box is fastened to printer fuse box.

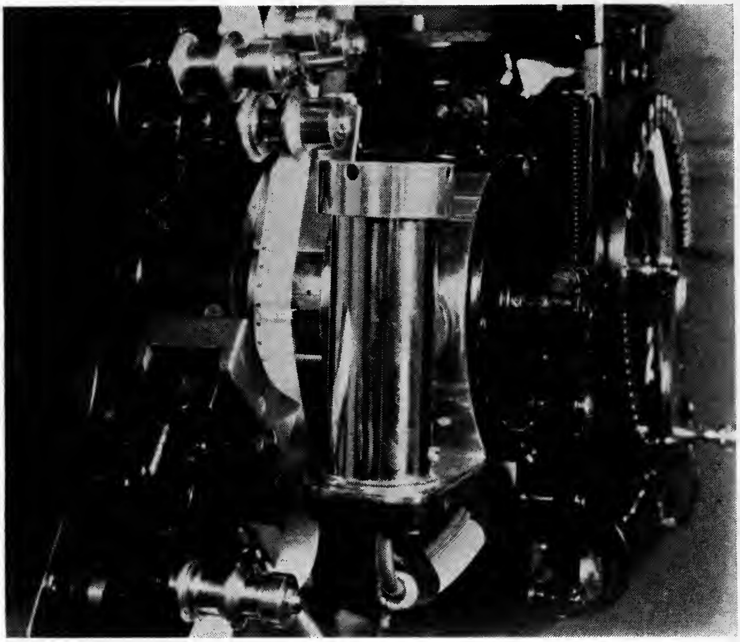


Fig. 3. Printer aperture with picture and sound lamps on. Air hose at bottom of lamp house is for cooling.

as the original slide did on the printer. With this design there is no need for a partition between the picture and sound which might cause shading of the track area.

A 50-w T-8 single-contact 120-v base lamp is used. The bracket for the lamp assembly is made from 14-gauge stainless steel formed to fit the printer housing and fastened on with two $\frac{1}{4}$-in. 20 screws. Formica is attached to this to hold the lamp base with an adjustment for moving the lamp up and down and around to center the filament. Also, a short length of stainless $\frac{1}{4}$-in. tubing is inserted in the base for a compressed-air hose for cooling. The lamp cover is a piece of tubing with a light-tight cap. One screw locks the cover to the lamp base to prevent accidental removal while printing. The little prism cover locks the prism in the aperture after it has been adjusted. The six 2-56 screws that held the slide in place are used to fasten cover and prism to the printer.

Figure 2 shows the unit installed on a printer. On the opposite side, attached to the fuse box, is a 7 × 9 in. radio chassis which holds a 0–150-v d-c meter, a 50-w 100-ohm variable resistor and a single-pole, single throw switch with a neon jewel light for Off and On of sound track lamp. The circuit is connected to the picture-lamp d-c power supply.

Figure 3 shows the printer aperture with a piece of raw stock in place with the picture and sound lamps on. At the bottom of picture air hose and lamp wires go to rear of printer. After printing tests were made, it was found that 86 *v* were correct for normal track exposure, which gives a long life to the lamp.

To install this unit, first remove the housing cover plates as for normal maintenance and cleaning. Then the aperture slide adjustment knob and eccentric cam are removed; also the slide and cover. These parts are left off the printer. After removing these parts there is exposed a $\frac{1}{2}$-in. hole where the adjustment knob was located. This is used for the light path from lamp to prism.

Next, two $\frac{1}{4}$-20 screws are removed along side of the printer gate. These are replaced with two round-head $\frac{1}{4}$-20 screws $\frac{1}{2}$ in. long to bolt the sound-lamp assembly to the housing. While doing this the filament is lined up with the center of the original hole that the adjustment knob was formerly in. The prism is placed in the aperture with its cover, which is left loose until the prism is adjusted for field and track placement. After the lamp is wired and the circuit connected to the power supply the final adjustment of the prism is made with picture and sound lamps on and a composite negative in the gate. Then the prism cover screws are tightened securely. In making this adjustment the lamp bracket may be moved slightly, as well as the lamp, to get the maximum light output. The housing cover plates are put back on and the printer is ready for an exposure test.

The prism is quite simple to adjust for track placement, and the field is good due to diffusion through the long prism. No condenser or reflector is needed, as the lamps burn far below their rated voltage (86 v for normal track on fine-grain release positive).

The electrical circuits for these units were made and wired to the printers by Arthur Rescher of McGeary-Smith Laboratories, where for more than two years they have been used with a great reduction of printing time and maintenance problems.

An Improved Carbon-Arc Light Source for Three-Dimensional and Wide-Screen Projection

By EDGAR GRETENER

Three-dimensional and wide-screen projection both require substantially more than the conventional amount of screen light. The super Ventarc has been designed to meet these requirements to such an extent that the screen lumens are only limited by the maximum density of radiant energy the film can take. If this value is set at 0.7 w/sq mm, the ultimate limit for a 35mm projection system will be approximately 50,000 lm, with no film shutter. This level of screen light has been attained at 150 amp.

Continuous Burning

The recommended operation time for three-dimensional projection is 60 min continuous burning of the arc. Mirror arcs of normal design can take positive carbons up to only 20 in. in length. The positive support or carbon-guiding mechanism requires a carbon stub of about 2 in., and so reduces the useful carbon length to 18 in. As the consumption rate shows some variations, a safety margin of 10% should be provided. This means a further reduction of the useful carbon length to about 16 in. Limited by this consumption rate, the most screen lumens a present-day reflector-type arc can produce with 80% screen distribution is 20,000, with an arc current of 115 amp and no film shutter.

Up to the maximum limit for smooth operation, the screen light a high-intensity arc can produce increases with the increasing consumption rate of the positive carbon, since the vapors produced by the evaporation of the carbon core constitute the light source. It thus becomes necessary for maximum light that any limitation on carbon consumption rate be removed. Such limitations can be overcome by an arc which is capable of continuous burning. In order to do this it becomes necessary to attach a new carbon to the burning one as soon as the latter is consumed to a minimum length determined by the carbon support. This problem of joining positives proved to be a very difficult one for a cinema arc, since no failure of the joining process can be tolerated with a continuous show. Furthermore, the quality of the joint has to be such that no flicker or color change of the projection light appears on the screen when the joint burns through the arc.

The process of joining positive carbons has been worked out by our firm in the past two years, with the kind assistance of the National Carbon Company. The

Presented on October 9, 1953, at the Society's Convention at New York by Hans Frey, Dr. Edgar Gretener, A. G., Ottenweg 25, Zürich, Switzerland, for Edgar Gretener.
(This paper was received July 2, 1953.)

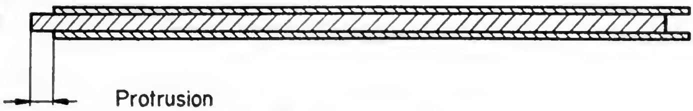


Fig. 1a. Positive carbons.

Figure 1b

results are now so satisfactory that this method is ready for practical use.

The nonrotating positive carbon of the Super Ventarc Lamp makes the joining problem much easier. From a practical point of view, the dimensional tolerances normally associated with large-scale production processes must be taken into consideration, so that a joining method requiring a very high precision of the parts to be joined would be of little practical interest. The positive carbons for continuous operation are designed as shown in Fig. 1a, so that the core protrudes at one end, with a complementary hole formed at the other. A magazine holding positive carbons is provided in the lamphouse. As soon as the length of the burning carbon reaches a certain value, a contact is operated which causes a new carbon to leave the magazine and be joined to the burning carbon, the hollow end of the new carbon sliding over the protruding core on the cold end of the burning one (Fig. 1b). The parts to be joined are impregnated by the manufacturer with a special cement. As the joint moves toward the positive head, it is heated by a simple electrical oven, which hardens the cement. The magazine can be designed to take any quantity of positive carbons, and it can be refilled while the arc is burning.

With the continuous feed for the positive carbons, an adequate system must also be provided for the negative electrode. To obtain maximum brilliance from the arc, the current density in front of the positive crater must be increased to the maximum extent possible, thus causing a high evaporation rate of the positive carbon. With a rod negative and an arc length of reasonable value, this would give rise to "mushroom" deposits on the tip of the negative, resulting in erratic burning. These difficulties are overcome by the use of a disk negative, mounted in a meridional plane of the illumination system. During operation of the arc, this negative disk is slowly rotated. All evaporation products condensing at the edge of the disk are thus transported outside the arc stream and oxidized in the open air. The disk consumes slowly at a rate dependent upon the arc current and other factors, and has a useful life of the order of five to ten hours burning time. The blown arc equipped with the continuous feed mechanism for the positives and combined with a suitably designed disk negative thus constitutes a source which can meet any requirement for cinema projection, within the limits imposed by the sensitivity of the film to the heat generated.

The Light Source

If the rate of evaporation of the core is high enough, the concentrated arc stream in front of the positive crater

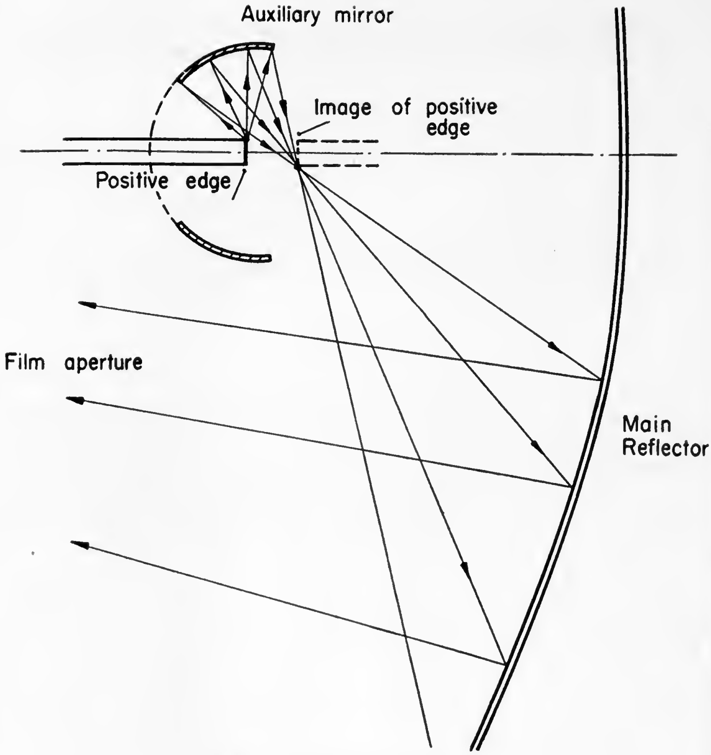


Fig. 2. Illumination system.

shows the same brightness as the crater itself. The absorption in the arc rises with increasing evaporation of the positive core until the crater edge is no longer visible through the arc. Under these conditions the arc stream replaces the positive crater as the light source. The brilliancy of this arc stream decreases with increasing distance from the crater. To get a cylindrical source of constant brilliancy along its axis, an auxiliary mirror is provided near the arc, as shown in Fig. 2. This auxiliary mirror picks up the back radiation of the arc stream and forms an inverse image of the arc in itself. Seen from the direction of the main mirror the arc stream seems to operate between two positive carbons (Fig. 2).

This light cylinder produces many more lumens than the crater itself, and in addition it offers much better conditions for the illumination system. Referring to Fig. 3a, a flat source produces a very sharp peak in the center of the film aperture if the collecting angle α of the mirror is increased to 90° in order to collect all the radiation of the flat source. This is due to the fact that the mirror-surface elements near the edge of the mirror see the source as a very narrow ellipse, with the small axis degenerating to zero for a 90° viewing angle. Because of this bad effect, the collecting angle of the mirror is normally limited to 70–75°.

In contrast with this, the cylindrical light source offers its very best qualities from a viewing angle of 90° to the carbon axis. This is illustrated in Fig. 3b.

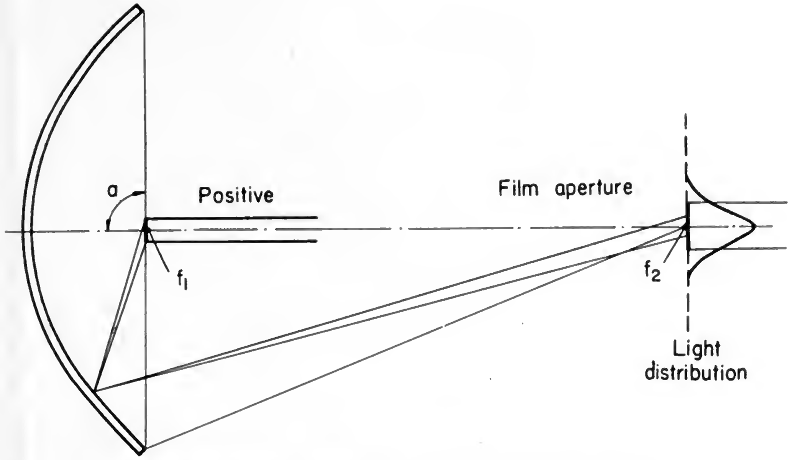


Fig. 3a. Elliptical reflector in focus $f_1 f_2$ flat source.

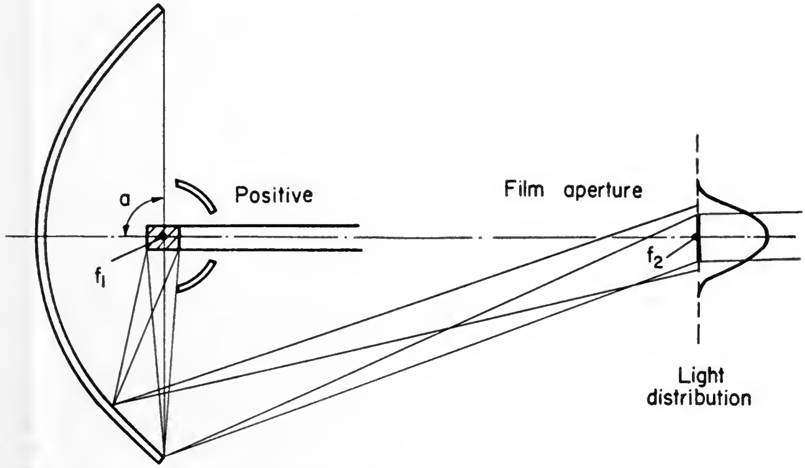


Fig. 3b. Elliptical reflector in focus $f_1 f_2$ cylindrical source with auxiliary mirror.

The illumination system of the Super Ventarc has therefore been designed to embrace the total solid angle around the source, the auxiliary mirror and the main mirror having each a collecting angle of about 90°.

The combination of the two mirrors not only picks up the total radiation from the cylindrical source, thus giving maximum efficiency for the illumination of the film aperture, but also prevents the lamp house from being heated by waste light from the arc.

Maximum Screen Illumination

The maximum possible light flux for a projection system is limited by the tolerable density of radiant energy in the film aperture. This limit is not precisely established, but it is known to be in the neighborhood of 0.7 w/sq mm (measured with no film shutter) for normal projectors without forced-air cooling. This unit value holds for every part of the film area, so that a hot spot in the center of the aperture limits the total screen lumens long before the tolerable density of radiant energy is reached for the sides and corners of the picture. For this reason, uniform screen illumination is desirable. In any event, bad light distribution is particularly to be avoided in the projection of three-dimensional and wide-screen pictures.

For highest screen lumens, the highest possible ratio of lumens per watt has to be provided at the aperture. Without heat filters, a high-intensity arc gives about 115 aperture lm/aperture w, with no shutter. Cutting all invisible radiation, this goes up to 230 lm/w. Further cutting of the red and blue end of the visible spectrum raises this ratio to 300 lm/w, if the white is permitted to shift one threshold toward green. This is not noticeable with a projection system if this greenish white cannot be compared directly with a correct white; and a light loss of no more than 1.75% is involved if all radiation beyond the range between 430 and 650 mμ is eliminated.

The ideal radiation filter transmitting 430 to 650 mμ will be of the interference type, but this is not yet commercially available; any practical filter will produce some light losses and transmit some invisible radiation. Further, the transmission factor T of a good surface-treated lens can be set to 0.90. Recognizing these factors, it is always useful to set up the final target. The ultimate screen lumen figure thus becomes:

$$L = A \cdot \delta \cdot \eta \cdot T$$

where A is the area of the aperture in sq mm,

δ is the maximum tolerable radiant energy at the aperture in w/sq mm,

η is the luminous efficiency of this energy in lm/w,

and T is the lens transmission.

Substituting the values:

A = 320 sq mm for 35 mm film,
δ = 0.7 w/sq mm,
η = 300 lm/w, and
T = 0.9, we get
$L = 320 \times 0.7 \times 300 \times 0.9 =$ 60,000 lm without the film shutter.

This value holds for an even light distribution over the screen. With an 80% side-to-center distribution, it is reduced to 50,000 lm.

Any light losses of the heat filter can be compensated by a slight increase of the arc current, and any transmission of invisible radiation can be suppressed by additional filter layers. Consequently the 50,000 lm will be available in the future if the cutoff at both ends of the visible spectrum can be made sharp enough and if projection-lens efficiency is 90%. This ultimate screen-lumen figure will grow proportionally if the heat tolerance of the film can be increased by forced-air cooling or the use of improved film material.

It must be pointed out that infrared transmitting mirrors are not suitable for very high-current arcs, as the support glass will be spoiled in a short time by deposits from the arc. The Super Ventarc uses a metallic mirror evaporated with aluminum and with a protective layer of silicon monoxide. This protecting layer is so thin that its heat resistance is quite negligible. If hot particles fall on the surface of this mirror, the high heat conductivity of the metal prevents local melting, so that the particles do not fuse with the mirror surface but fall harmlessly to the bottom of the lamphouse. Comparative tests with a very heavily loaded positive crater showed the striking superiority

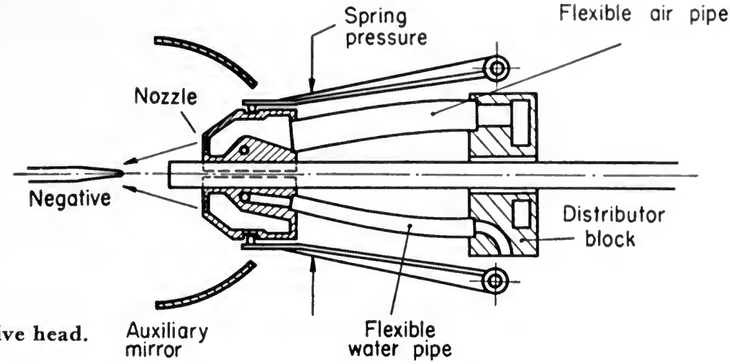


Fig. 4. Positive head.

of the metallic mirror with regard to these sputtering effects.

Color Projection

Three-dimensional and wide-screen projection must be combined with color. Since the picture is so much more realistic, the very best color has to be provided, and any color errors are much more noticeable than with a normal two-dimensional picture.

With subtractive color, the color quality is directly related to the transparency of the film, in such a way that really good color is only available with prints of high density. This is true as long as such dyestuffs as change saturation and hue with varying density are used for subtractive color.

Since color for three-dimensional and wide-screen projection has to be of the highest quality, it would not be practical to try to obtain more screen light for these processes by making color prints of higher transparency than that usual today for normal two-dimensional pictures.

Progress in Design Since 1950

In an earlier article[1] the author described a Ventarc giving a maximum output of 30,000 screen lm with 100 amp. The Super Ventarc presently described shows substantial progress in comparison with the technique used in 1950. The main improvements may be summarized as follows:

1. The Super Ventarc is provided with a magazine feed for the positives for continuous burning of the arc. Relatively short carbons can be used with this operation, thus giving better basic conditions for the optical illumination system. The 45° deflection mirror used with a vertical carbon in the earlier lamp can thus be avoided, and the positive is now arranged in the conventional horizontal position.

2. The design of the positive head has been improved by separating the carbon guide from the contact pieces, so that the centering of the positive is no longer affected by any wear of the contact pieces. These contacts are shaped as half cylinders, are directly water cooled, and each incorporates an air nozzle. Water, arc current, and compressed air are fed to the two contacts through flexible connections from a central distributor block. The carbon guide pieces are assembled with this block to form a stable unit. The contact pieces are pressed against the positive by a spring system which allows the contacts to adhere perfectly to the surface of the positive, without influencing the correct centering of the carbon (Fig. 4).

---

[1] Edgar Gretener, "Physical principles, design and performance of the Ventarc high-intensity projection lamps," *Jour. SMPTE, 55:* 391–413, Oct. 1950.

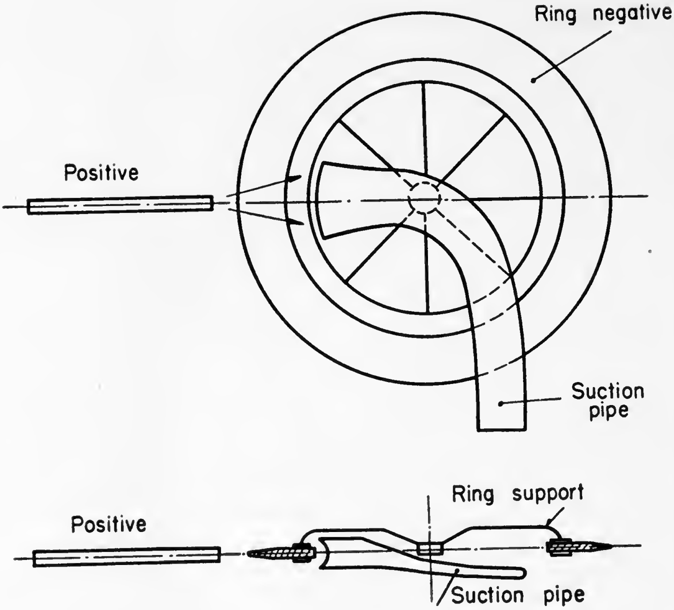


Fig. 5. Negative electrode.

3. The big negative ring used in 1950 which surrounded the positive head is now replaced by a much smaller one, located entirely at the negative side of the arc, and penetrating the elliptical reflector through a suitably shaped slot. With the metallic reflector used, this proved to be possible without sacrifice of the optical precision.

Figure 5 shows the negative-electrode arrangement, in which a suction pipe picks up the hot arc gases at the inner side of the ring negative. This arrangement permits a very simple design of the negative support and its driving mechanism.

4. As the main reflector, together with the auxiliary mirror, embraces the total solid angle round the arc stream, the front part of the positive head and the main reflector are not directly accessible for inspection and cleaning. For this reason, the whole negative part of the lamp mechanism, including the main reflector, the suction pipe and the negative drive is arranged to swing out around a vertical axis, thus giving the very best accessibility to all the important parts requiring service attention. The suction pipe is designed to go through this axis of rotation, so it need not be disconnected.

5. The blower producing compressed air for the positive head and suction for the negative pipe is arranged at the top of the lamphouse. It is driven very smoothly and silently by an induction motor. The lamphouse is ventilated by an ejector system driven by the exhaust of the suction pipe. This design proved to be more effective and less costly than the ejector system used in 1950. Furthermore, it avoids the necessity of providing additional blowers outside the lamphouse.

6. The heat filter has been arranged in a slide near the dowser, so that it can easily be taken out for inspection and cleaning.

The main reflector of the Super

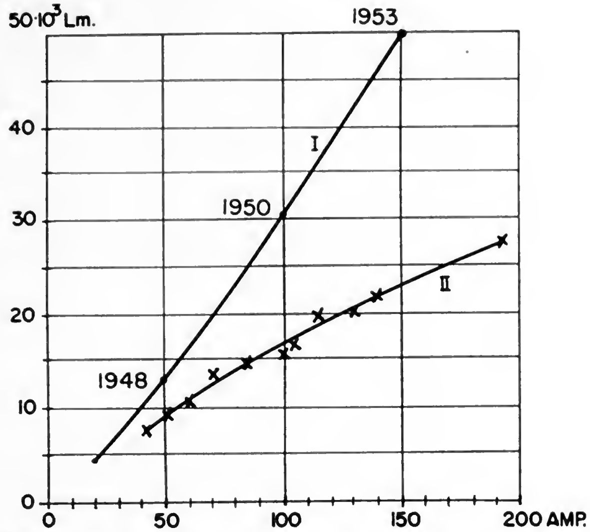


Fig. 6. Screen lumens, side-to-center ratio 80%: I, Ventarc lamps; II, conventional reflector-type arcs (NCC).

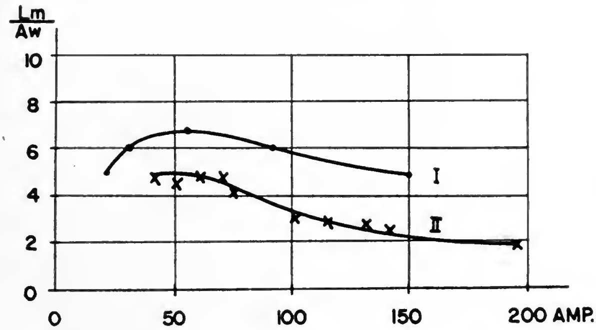


Fig. 7. Lumens per arc watt: I, Ventarc lamps; II, conventional reflector-type arcs (NCC).

Ventarc has been enlarged to a diameter of 24 in. This gives the necessary space for the positive head with the auxiliary mirror, the ring negative and the magazine feed for the positives, without causing any substantial light losses due to shadow masking of the illumination beams.

The big lamphouse associated with the 24-in. mirror gives the necessary safety margin for operating the arc, even with extremely high load.

The Screen Light From the Super Ventarc

Figure 6 gives the screen lumens of the Ventarc Lamp in which the range between 100 and 200 amp is covered by the Super Ventarc (SVA). It will be noted that a screen lumen level of approximately 50,000 lumens without shutter has been attained at 150 amp. Screen lumens per arc watt (lm/arc w) are plotted in Fig. 7. This value represents

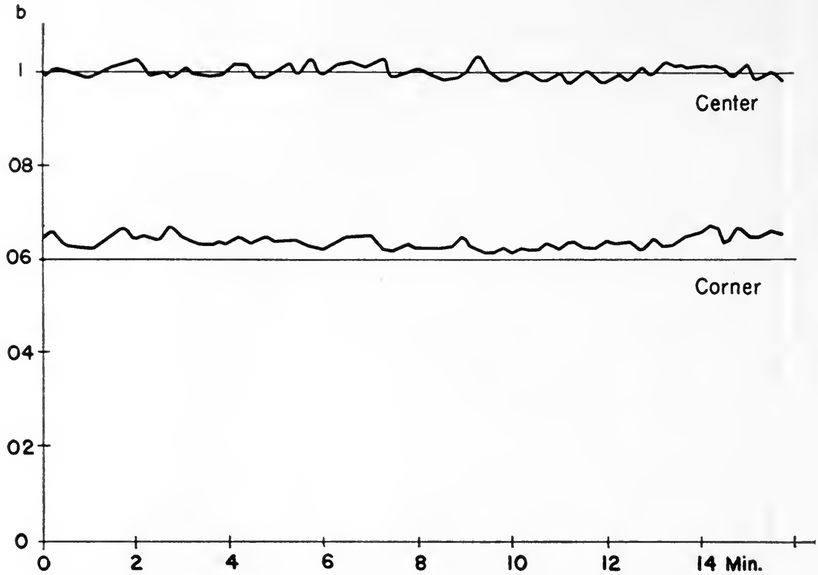


Fig. 8. Super Ventarc, 150 amp, screen light variations with time; b, relative brightness.

a figure of merit for the efficiency of the arc lamp. The distinction between arc watts as involved here, and the aperture watts used in earlier lumen-per-watt calculations should be noted. For comparison, the corresponding figures for conventional reflector-type arc lamps are plotted in the same diagrams. These figures have been taken from the paper by Holloway, Bushong and Lozier,[2] giving a survey on screen illumination with carbon arc 35mm motion-picture film projection systems. It should be noted that the most powerful arc of conventional type described there, run with 195 amp and giving 28,000 screen lumens with a side-to-center distribution of 80%, is only an experimental one. In contrast, the Super Ventarc figures stand for performance values which can be guaranteed for practical use.

The screen light from the Super Ventarc is homogeneous over the screen with regard to its spectral composition. The red-to-green ratio of the light measured at center, sides and corners of the screen shows no variation exceeding the measuring precision. This homogeneity is of importance for the projection of high-quality color films.

The screen light variations with time for center, sides and corners of the screen are shown in Fig. 8. It is seen from this diagram that the Super Ventarc meets the highest requirements which may be set up for three-dimensional and wide-screen projection regarding stability of screen illumination.

[2] F. P. Holloway, R. M. Bushong and W. W. Lozier, "Recent developments in carbons for motion-picture projection," *Jour. SMPTE, 61:* 223–240, Aug. 1953.

(*See page 532 for Convention discussion of this paper.*)

Performance of High-Intensity Carbons in the Blown Arc

By C. E. GREIDER

The performance of carbons operated in the Gretener type of "blown arc" shows the following advantages as compared with the more usual method of burning: (a) from 5 to 25% less current is required to produce the same light; (b) at the higher brightness levels, less carbon consumption is required for the same light; (c) the maximum light that the carbon will deliver is increased by 10 to 20%; and (d) uniformity of brightness across the face of the arc crater is considerably improved. The performance advantages of the "blown arc" seem to be considerably greater for 12-mm than for 10-mm carbons, and are greatest when the carbon is operated at or near its maximum current and light output. The addition of blowing to the arc introduces special problems regarding the design and operation of the negative electrode.

THE "blown arc" as described by Gretener[1] is strikingly different in appearance from the more usual form of the high-intensity carbon arc. The object of the present work was to determine whether this change in the shape and appearance of the light source produces a change in its light output, and more specifically, its effect on the relationship between light output, arc current and rate of consumption of the positive carbon.

Presented on October 9, 1953, at the Society's Convention at New York by C. E. Greider, Research Laboratories, National Carbon Co., a Division of Union Carbide and Carbon Corp., Cleveland, Ohio.
(This paper was received August 31, 1953.)

In the Gretener "blown arc," the positive carbon is surrounded by a magnet coil to "homogenize" the arc, together with a ring of air jets which direct a conical stream of air inward toward the arc. The latter changes the character and direction of the arc flame so that, instead of curving upward as it leaves the arc crater, it is concentrated and projected straight forward from the crater. The negative electrode is directly in front of the positive, in the path of this arc flame, which without the blowing would give an extremely unsteady arc at the high currents used. If a carbon rod of the customary shape is used for the negative electrode, deposits of carbon or rare earth carbide tend to form on its tip,

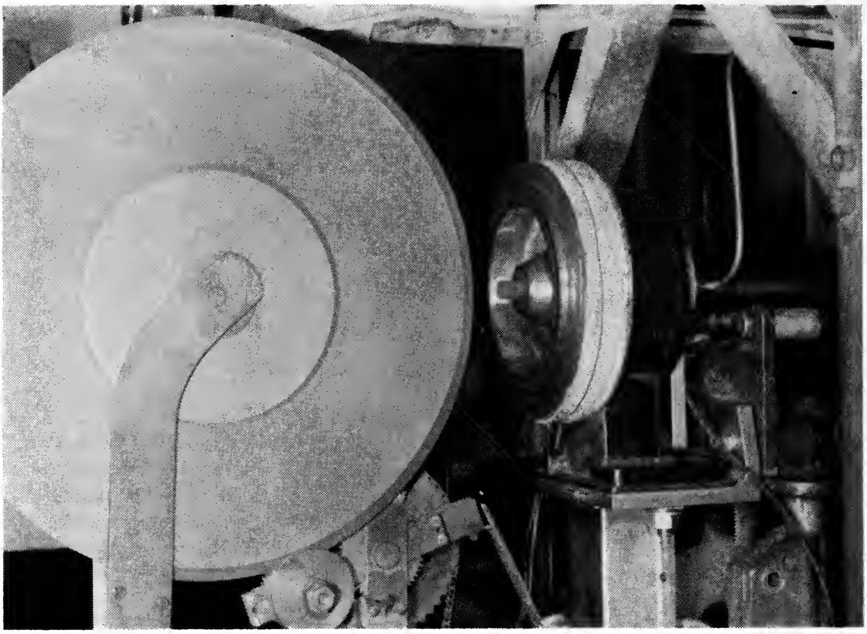


Fig. 1. Arc lamp mechanism for the "blown arc," using 12-mm positive carbons and a graphite disk negative.

causing unsteady operation. This can often be alleviated by small changes in the composition of the negative carbon or in its alignment. A preferred solution may be the substitution of a slowly rotating graphite disk as the negative electrode, as described by Gretener.[1] This does away with the formation of either mushroom carbon or rare earth carbide on the negative, but it is too early as yet to say whether it has eliminated all the problems associated with the negative electrode that are introduced by the addition of blowing to the arc.

Figure 1 shows the "blown arc" mechanism installed in an experimental test lamp, using the graphite disk negative. Figure 2 is a photograph of the "blown arc" in operation, using the same negative with a positive carbon of 12-mm diameter. The arc length is held at 15 mm, and the protrusion of the positive carbon from its holder is also 15 mm.

Since this work was designed to evaluate the effect of blowing, measurements with the same carbons were also made without blowing, keeping all other operating conditions the same as in the "blown arc" so far as possible. The same experimental test lamp was used, with silver water-cooled jaws previously described,[2] since water-cooled jaws are also used in the "blown arc" in order to obtain maximum performance from the high-brightness carbons used. The same positive protrusion of 15 mm was maintained. The angle between the axis of the negative and positive carbons was 53°, which when the arc is operated without blowing, seems to give the best performance with the carbons and arc currents used.

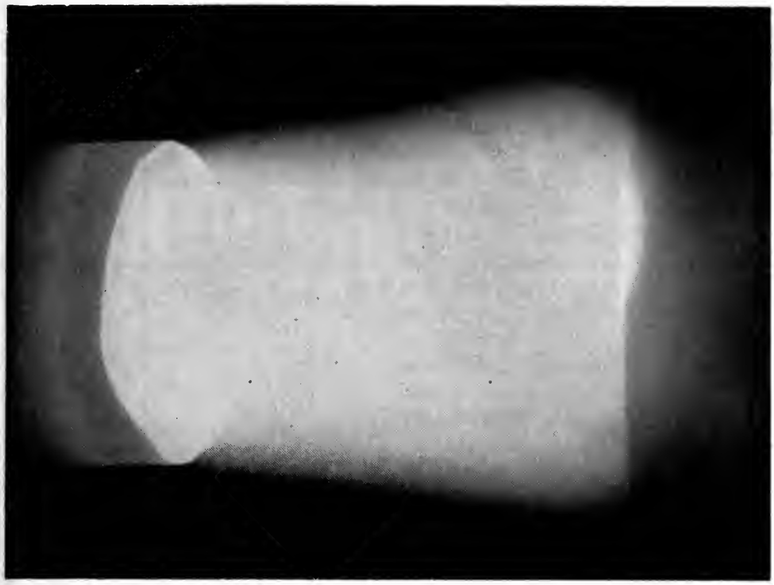


Fig. 2. The "blown arc," with 12-mm positive carbon and graphite disk negative.

Methods of Light Measurement

The light output with or without blowing was measured directly in terms of brightness at the crater of the arc, without consideration of any particular optical system. Direct crater-brightness measurements have the advantage of showing changes in brightness distribution across the crater face, which demonstrate more clearly the causes of observed differences in total light output. They can also be used to predict with reasonable accuracy the projection performance in any assumed optical system.[3]

All the measurements of arc-crater brightness were made at an angle of 50° from the axis of the positive carbon. Both the brightness and the light output of the arc crater will vary with angle of view; the choice of 50° represents a reasonable midpoint, since a typical mirror system will collect about the same amount of light in the outer zone beyond 50° as it will in the zone inside this angle.

Where the "blown arc" is shown by these measurements to have an advantage over conventional operation, this advantage may be greater in terms of screen light than is shown in the comparisons of crater brightness at 50° if a mirror with a large collecting angle is used. In the "blown arc," considerably more light is generated in the space directly in front of the crater. Measurements limited to crater brightness do not indicate the contribution which this cone of light in front of the crater can make to the total screen light, especially the light collected by the outer zones of the mirror, or by an auxiliary mirror.

The brightness across the crater face was measured by the method described by Jones, Zavesky and Lozier[4] in which a photocell is driven across a projected image of the crater, in synchronism with a recording meter which is calibrated (with the photocell) to give a direct reading of intrinsic brightness. Curves of crater brightness versus position are thus obtained across the crater face both horizontally and vertically through the center of the crater image. From these curves, the maximum and center brightness can be read directly, and the average brightness can be readily calculated. To facilitate comparison, this average brightness is calculated only for a circular area of 10-mm diameter centered on the crater, when using 12-mm carbons or 8-mm diameter with 10-mm carbons. Because of the greater spindle in the "blown arc," the actual diameter of the arc crater will be only a few tenths of a millimeter larger than that of the area used for measurement of brightness.

This average brightness is independently determined by a second method suggested by Gretener, in which the entire image of the crater is projected onto the face of a photocell, using a much lower magnification than in the preceding case. The photocell is masked so as to admit only the light from the central 8 or 10 mm of the crater. Since the crater is viewed from an angle of 50°, this mask is elliptical rather than circular. These two methods of measuring crater brightness give excellent agreement, the difference between them being no more than 2 or 3%.

The Carbons

The comparisons reported below were all carried out with experimental carbons similar to the high-brightness type (Ultrex) carbons whose performance characteristics were recently described by Holloway, Bushong and Lozier.[5] A few comparisons made with carbons not designed to give so high a brightness have shown that blowing has about the same effect on performance as with these "high-brightness" carbons. Two different sizes of carbons were used, having diameters respectively of 10 and 12 mm. The 10-mm carbon is the one used in the "Super-Ventarc" described by Gretener in this issue of the *Journal*, while the 12-mm carbon has been used experimentally in the projection of theater television by the Eidophor process. With each carbon size, the core size and composition were selected to give the best efficiency in terms of current requirement and carbon consumption, consistent with steadiness of operation.

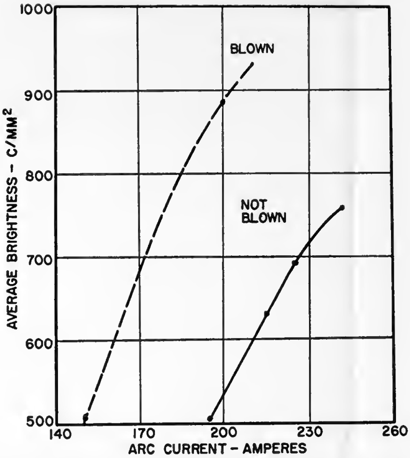


Fig. 3. Reduction in current requirement with "blown arc" operation. 12-mm high-brightness carbons.

Comparative Results

The most outstanding and consistent effect of blowing is the lower current that is required to give the same light (or average crater brightness). This has been found true for all grades and sizes of carbons that have been examined. The magnitude of the difference is shown in Fig. 3 for the 12-mm high-brightness carbon. With this particular carbon the decrease in current required is from 30 to 40 amp or from 15 to 20%.

One reason for the lower current requirement in the "blown arc" is the smaller diameter of the arc crater at either the same current or the same brightness. This is caused by the air jet, which increases the oxidation or spindle on the outside of the shell. The amount of this difference will depend on

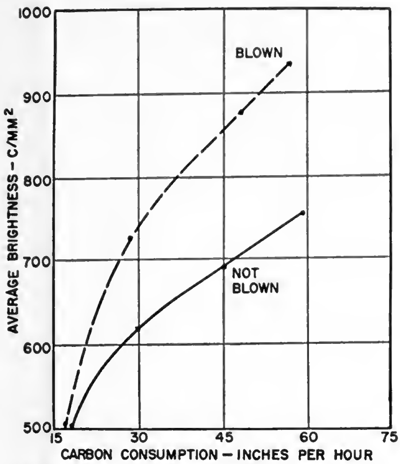


Fig. 4. Effect of "blown arc" operation on carbon consumption. 12-mm high-brightness carbons.

operating conditions, but for 12-mm carbons the "blown arc" at the same brightness will have a crater from $\frac{1}{2}$ to 1 mm smaller in diameter than obtained without blowing. A lower arc current will, therefore, be required with the "blown arc" to give the same current density at the crater, because of the smaller crater area over which the current is spread.

This smaller crater diameter, however, is not enough in itself to account for all the decreased current requirement. The effect of this factor can be eliminated by decreasing the shell thickness of the carbon when operated without blowing in order to compensate for the extra carbon that is burned away in the "blown arc," keeping the carbons otherwise identical.

Such a comparison shows that the smaller crater diameter of the "blown arc" is responsible for less than half of the decrease in current requirement. The rest may be due to the effect of the air jet in keeping the arc off the sides of the carbon, so that all the current is discharged in the crater itself. An alternative explanation is that the redirection of the arc flame produced by the blowing permits more effective utilization of the light-giving material (rare earth vapors) in the production of usable light.

The "blown arc" also requires lower carbon consumption for the same light output, especially at high levels of average brightness. This comparison is shown in Fig. 4 for the same 12-mm carbons of Fig. 3. The carbon consumption is about the same for either type of operation at an average crater brightness of 500, but as brightness is increased beyond this point, the "blown arc" shows increasingly greater superiority. It can also be run at a higher level of average brightness. This highest brightness obtained with this carbon without blowing (as normally operated) was no more than about 800 cp/sq mm, while in the "blown arc" it can readily be made to exceed 1000 cp/sq mm.

The principal reason for the higher average crater brightness with the blown arc is a much more uniform brightness distribution across the crater face. The light intensity at the point of maximum brightness is little if any higher, but a larger proportion of the total crater area equals or approaches this maximum brightness. This is illustrated in the curves for brightness distribution across the crater face for the two types of operation, shown in Fig. 5. At the point of maximum brightness near the center of the crater, both carbons show the same brightness of about 1400 cp/sq mm. Without blowing, however, the brightness falls off much more rapidly as the crater edge is approached. The "blown arc," therefore, can give much higher average crater brightness for the same center or maximum brightness.

The curves of Fig. 5 show also that with our conditions of measurement, the greatest improvement in uniformity and increased light output from the "blown arc" appears in the brightness curve measured in a horizontal plane through the crater. This gives a clue to the reason for the improvement.

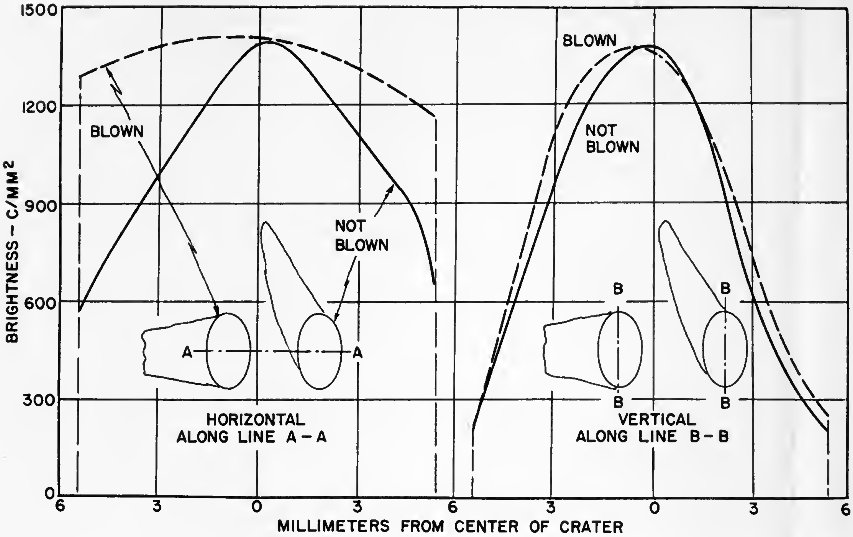


Fig. 5. Brightness distribution across the crater face with "blown arc" and conventional operation. High-brightness carbons with same core and crater size.

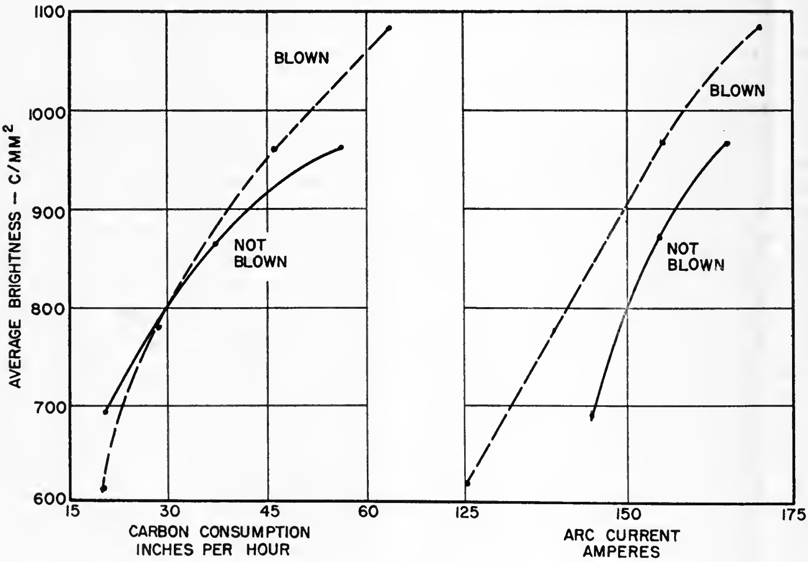


Fig. 6. Effect of "blown arc" operation with 10-mm high-brightness carbons.

Table I. Performance of "Ultrex" Type Carbons in the Blown Arc.

	Current, amp	Arc voltage	Carbon consumption, in./hr	Avg crater brightness cp/sq mm
10-mm carbons	125	60	20	610
	140	63	28	780
	155	71	46	960
	170	78	64	1080
12-mm carbons	150	55	17	505
	175	64	28	725
	200	71	48	875
	210	75	56	935

Without blowing, the "tail flame" is directed upward and away from the arc, and most of its light is not used, as shown in the sketches of the arc image in Fig. 5. In the "blown arc" this flame is concentrated and projected straight forward from the crater. Even if only crater brightness is measured, the brightness along the horizontal plane A–A is built up considerably by this addition from the arc flame, while if the optical system is so designed as to pick up light effectively from the area in front of the crater, the increase in usable light may be even greater. The increase in light appears principally in the horizontal brightness distribution curve because the 50° angle of view was in a horizontal plane with respect to the carbon axis; if the angle of view had been in a vertical plane, the increased light would have been mostly in the vertical brightness distribution curve.

The advantages of the "blown arc" seem to be somewhat greater with 12-mm carbons than with the 10-mm size. A typical comparison with 10-mm high-brightness (Ultrex) type carbons is shown in Fig. 6. It is seen from this that with the "blown arc", less current is required to produce the same brightness, but that the difference between the two is not as great as with the larger size. The 10-mm carbon as a "blown arc" does not show lower carbon consumption for the same brightness until the average crater brightness exceeds 800 cp/sq mm. As with the 12-mm carbon, the advantage in carbon efficiency increases as the brightness is increased, and the carbon is able to reach a higher average brightness in the "blown arc" than without blowing.

The light output of the "blown arc" is affected to some extent by operating conditions such as the strength of the applied magnetic field, the air pressure in the stabilizing air jets, and the effectiveness of the water cooling at the positive carbon jaws. Normally, however, variation of these factors which still permits satisfactory "blown arc" operation will not affect light or carbon consumption by more than about 5%. Typical values for current, carbon consumption and light (average crater brightness) are given in Table I for the 10- and 12-mm high-brightness type of carbons operated in the "blown arc."

The results of this work lead to the conclusion that "blown arc" operation permits a carbon to deliver considerably more light and to deliver the same amount of light at both a lower current and a lower rate of carbon consumption. Its advantages seem to be greater with 12-mm than with 10-mm carbons, while with a given carbon the superiority of blowing is greatest at the highest light output the carbon is capable of delivering. This type of operation should, therefore, find its greatest usefulness in conditions requiring an extremely high light output.

References

1. Edgar Gretener, "Physical principles, design and performance of the ventarc high-intensity projection lamps," *Jour. SMPTE, 55:* 391–413, Oct. 1950.
2. M. T. Jones and F. T. Bowditch, "Optimum performance of high-brightness carbon arcs," *Jour. SMPE, 52:* 395–406, Apr. 1949.
3. M. T. Jones, "Motion picture screen light as a function of carbon-arc-crater brightness distribution," *Jour. SMPE, 49:* 218–240, Sept. 1947.
4. M. T. Jones, R. J. Zavesky and W. W. Lozier, "Method for measurement of brightness of carbon arcs," *Jour. SMPE, 45:* 10–15, July 1945.
5. F. P. Holloway, R. M. Bushong and W. W. Lozier, "Recent developments in carbons for motion-picture projection," *Jour. SMPTE, 61:* 223–240, Aug. 1953.

Discussion on "An Improved Carbon-Arc Light Source for Three-Dimensional and Wide-Screen Projection," by Edgar Gretener

[After the paper, E. I. Sponable of Twentieth Century-Fox announced that the model on display was the first factory model and that its operation would be demonstrated later at the Twentieth Century-Fox laboratory.]

David B. Joy (National Carbon Co.): Referring to Fig. 6, a value of about 50,000 lumens is indicated for the Ventarc lamp. This value is, as Mr. Frey pointed out, about twice as high as what is now available in many of our largest theaters. In view of this, it is natural to wonder what measurements have been made of the heat at the film aperture.

Mr. Frey: As Mr. Sponable has already explained, the lamp has only recently been finished, so the values shown in the figure may not be final, but may be indicative. At exactly 150 amp we measured 48,000 lumens on the screen, that is screen lumens with a distribution of about 75%. In this case, the radiation energy at the center of the gate was 1.25 w/sq mm, which is about 30% less heat per unit of light than with the conventional arc. This radiation energy produces 48,000 screen lumens, while the same radiation energy for a conventional arc would be about 35,000 screen lumens.

Mr. Sponable: Some of you here might be interested in what we are going to do with a lamp of this type. It was originally designed for use with the Eidophor, and normally would have been finished when the commercial models of the Eidophor are ready later this fall. However, because we have the problem of showing CinemaScope on very large screens, particularly drive-ins, the use of such a lamp seems to be a possible solution for the drive-in problem.

Specifying and Measuring the Brightness of Motion Picture Screens

By F. J. KOLB, JR.

Screen brightness is measured and specified in order to control viewing conditions for projected pictures. By the modulation of light from the projector the whole artistic creation captured in the production of a motion picture is presented to its ultimate audience. This creation can only equal the director's concept when viewing conditions are known and predictable. The control of screen brightness and the screen-image transfer characteristic is therefore a necessary condition for the most effective presentation of motion pictures. Brightness characteristics of projected pictures are discussed and the various practical simplifications considered. Nine conditions of screen-brightness measurement are described, specifications for the meters required are developed, and several simplified practical procedures for field measurement are detailed.

In 1941 the Subcommittee on Screen Brightness of the SMPE Theater Engineering Committee undertook the job of determining how screen brightness should be measured and of specifying instruments suitable for the job, so that it would be more convenient to obtain data and study the viewing conditions of theater projection. Valid information on current practices, the Committee felt, was essential before any fundamental review of the 1936 temporary screen-brightness standards could be attempted, and before any improvement in theater viewing could be proposed.

Preliminary work led to specifications for an Illumination Meter and a Brightness Meter; these specifications were published in the October 1941 Committee report (*Jour. SMPE, 38:* 81–86, Jan. 1942).

Little progress was made during the war on the development of commercial instruments to meet these specifications. The problems of screen brightness had become of sufficient importance, however, that in the reorganization of the Society's committees, an independent Screen Brightness Committee was established in 1946. In March 1947 the Committee agreed to go ahead with what

A report prepared by the Subcommittee on Instruments and Procedures of the SMPTE Screen Brightness Committee. Subcommittee members are W. F. Little, A. Stimson, H. E. White and F. J. Kolb, Jr., Chairman. (Received for publication September 21, 1953.)

Note: Nomenclature throughout this report follows ASA Z7.1-1942, "Illuminating Engineering Nomenclature and Photometric Standards."

instruments were available, and determine the operating conditions in a small sample of theaters, in order to know what conditions would have to be met in a larger theater survey, to find out how well available instruments would perform, and to determine the practicality of surveying a significantly large number of the theaters at that time. Results of this preliminary survey were published in the Committee report of October 1947 (*Jour. SMPE, 50:* 254–276, Mar. 1948).

During the next four years the Committee had several instruments submitted for test, considered the limitations of equipment used in the 1947 survey, discussed what additional specifications should be formulated, and then undertook an enlarged theater survey using pilot-model instruments. The results of this survey eventually included more than 125 indoor theaters, divided among the various sizes of commercial theaters and located in several national geographic areas; data were published in the Committee reports of May and October 1951 (*Jour. SMPTE, 57:* 238–246, Sept. 1951; and *57:* 489–493, Nov. 1951).

At the Committee Meeting on February 2, 1950, a Subcommittee on Instruments and Procedures was appointed to review the problems of instrumentation and measurement. From the beginning it has been the purpose of this Subcommittee to express the instrumentation requirements for screen-brightness research and control, rather than to describe existing equipment. At succeeding meetings, the proposals of this Subcommittee have been discussed, modified and the intent re-examined, so that this report is presented as a statement and review of needs as they are presently understood.

Significance of Screen Brightness

Motion-picture films provide a form of visual art and communication dependent entirely upon the modulation of light. There is a sharp break in the presentation of motion pictures between the creative, preparatory work that produces a final image on motion-picture film, and the subsequent task of presenting this creation to the audience for whom it is intended. The director, producer and their staff cease any supervision of the project and turn the whole material over to the projectionist for him to present. Working solely with light to convey the visual content of this motion-picture film, the projectionist is concerned with the production of light, its concentration on the film, its modulation by the varying densities of the image, its collection in the projection lens, its reconvergence in an enlarged version of the photographic image, its re-emission from the projection screen, and finally its perception by the audience.

The eventual success of the creative thought and work producing a motion picture is dependent upon the successful modulation of the projection light in the exact manner visualized by the director when he approved the final work print. Yet many factors in the final presentation are subject to wide variation, beyond the director's control. The maximum brightness of the highlight areas in the picture as perceived by the audience is limited by the attainable screen brightness when the projector is operated with clear film in the gate; the minimum brightness of the shadow areas is limited by the stray and re-reflected light reaching the screen when the projector images an opaque target. Furthermore, the color of the screen light influences the faithfulness of screen reproduction, and the screen environment has great effect upon the illusion. These and similar factors together control the apparent contrast and mood of the picture, modify the highlight and shadow detail, determine the intelligibility of the picture information, and affect the psychological impact of the images.

The artistic creation may be presented effectively or poorly depending upon the control of the many factors of screen brightness, and upon their agreement with anticipated values. The present success of projected pictures is evidence that much has been accomplished; even these successes have pointed out that much more is yet to be done.

Characteristics of Screen Brightness

Brightness of motion-picture screens is at first approach a simple subject and most of the measurements, treatments, and surveys have made enough assumptions to realize this simplicity. When the complete problem is considered, however, there are many interacting physical factors that determine the ultimate audience perception of the visual image. While simplification is often permissible and even desirable, *it is important to know at all times what assumptions have been made, and to remember that the brightness at a particular point on the motion-picture screen and the brightness differences across the screen depend upon the projector, the motion-picture film, the auditorium, the screen and the position of the observer.*

Considering a single point on the screen, the *brightness at that point* depends upon (1) the brightness of projection source and the transmission loss, determined by the projection equipment; (2) the loss during transmission of the beam to the projection screen (which is usually negligible) and the gain in brightness resulting from auxiliary lighting in the auditorium and re-reflections of screen light and flare of projected light (which altogether may be appreciable); (3) the reflection characteristics of the screen, including not only its efficiency but also its response to incident illumination at an angle which is seldom 90°, and its ability to direct energy along the variable reflection angle toward the particular spot occupied by the observer in the audience. For any single observer in the audience the *distribution of brightness across the screen* depends further upon (4) the brightness distribution in the projection aperture; (5) the pattern of photographic density on the motion-picture film; (6) the characteristics of the projection optics; and (7) the variation in angles of incidence and reflection from various portions of the screen surface.

Relatively constant factors in this grouping are determined for any particular theater by the equipment and the theater design. For example, the brightness of the projection source and the transmission losses of the complete optical system are practically constant for any measurements made in one specific theater. The gain in screen brightness from surround illumination and re-reflected light, has a constant component from the specific auditorium lighting, plus a variable component representing the re-reflected screen light. (This re-reflected light, of course, varies with changes in the subject matter on the screen.) The distribution of light incident upon the photographic image in the projection aperture is roughly predictable from the type of projection equipment and the details of its alignment and adjustment. (This distribution, however, may vary significantly with changes in the position of the carbons. With some equipment this variation is noticeable only if the arc control point tends to wander during the operating cycle; other equipment may be optically so critical that even constant attention of the projectionist to this one part of his duties may be insufficient to avoid measurable and noticeable changes in brightness distribution.)

Chief variable factors are those which depend upon observer position in the audience, and of course upon density distribution in the photographic intermediate.

For any projection screen the importance of specifying the angles at which light reaches the screen from the projector and the angles through which light is reflected to reach the observer can be of extreme importance, as shown by Berger,[1] and D'Arcy and Lessman.[2] Many times it has been assumed that motion-picture screens are perfect diffusers whose brightness is constant for all directions of viewing. It is further usual to go beyond the original limitations defining such diffusion, and to assume that the brightness is constant in all directions even though the screen is illuminated at some angle other than the normal to its surface. While some of the common motion-picture matte screens approximate such a behavior, it has been shown that many of the commercial matte screens are measurably different — and actually that many screens are purposely designed to differ from such a perfect diffuser. Data presented by Lozier[3] show some commercial use of directional screens in motion-picture theaters; their use is presumed to be even more common in schools, industrial auditoriums, etc. Both the search for higher screen brightnesses together with the development of practical commercial procedures for making directional screens may be expected to produce a more widespread use of such materials. Directional screens offer the advantage of controlling brightness as a function of the angles of incidence and reflection; they are difficult to measure and evaluate for the same reason. In any installation, the angles of incidence and reflection vary significantly for different areas on the screen from any one observer position, and they usually vary even more from one observer position to another in the audience.

During the SMPTE screen-brightness surveys the theater screens were examined visually for evidence of directional reflection, but the classification was qualitative. It was possible, for example, to recognize the metalized screens, and data in these theaters are so identified. In most of the other theaters, however, directional effects of lesser magnitude presumably were not determined because the portable equipment commonly available does not conveniently provide the data for describing such screens.

Variations in subject matter — and therefore of image transmission and distribution — are, of course, not usually determined by theater survey; this information can be obtained more conveniently through laboratory measurements of properly chosen samples. In this report we shall limit ourselves to pointing out the importance of such information, together with the present lack of adequate data. Obviously it is never intended that the audience view a "bare screen," and bare-screen brightnesses have no direct significance! Projected pictures themselves are the true interest of audiences, and the brightnesses of the pictures themselves are basically what measurement seeks to determine, and what standards intend to control. It may be true that variations in film transmissions and in other factors relating bare screen to picture brightnesses occur less frequently, but they can be of considerable magnitude and it must be realized that they can appear at any time.

Despite the convenience and frequent necessity of separating the film-transmission variable from the other factors, it has been shown that our knowledge of transmission factors is inadequate.[4] This Committee recommends that a thorough study of picture densities be undertaken as an essential part of the screen-brightness problems. Particularly when the motion-picture engineer calls upon those in other fields for assistance (as he must in any problem so complex as the viewing of projected pictures) it is important to delineate the assumptions and definitions of our common ground.

Finally, in this group of variables of unusual significance, one must always realize that the problem of screen brightness is at its simplest still a problem of tone reproduction. Not only is the maximum brightness of importance, but also the minimum brightness — and the nature of the brightness scale in between. Control of screen brightness implies control of a transfer characteristic, relating the screen image to the original creative visual sensation. It has been customary to simplify the problem by assuming that control of maximum brightness simultaneously controlled the shape of the entire transfer characteristic, and for a certain class of theater designs there was a limited constancy. Projected pictures are now viewed under such a range of conditions, however, that all the assumptions on viewing conditions must be checked to confirm their validity.

Theater Measurement of Screen Brightness

To answer the practical need for data on the viewing conditions for projected pictures, and to determine whether a particular installation is operating within the range of standards and recommendations, field measurements are necessary. These data are customarily obtained under conditions that involve many assumptions, made because of instrument limitations, necessity for minimizing measurement times, necessity for portability and independence from laboratory facilities, and other factors of general convenience.

Table I summarizes some of the possible measurement procedures, specifies the cognate assumptions, and notes details of equipment and procedures. The more detailed measurements may be necessary for research workers; the less detailed measurements should interest practical projectionists.

The Appendix presents in more detail the specifications for the instruments themselves,* and for procedures for their use, recommended by the Screen Brightness Committee. In many cases these specifications include the best present compromise between what would be desirable and what it is practical to obtain. This summary is intended as a reference for the Committee and the industry on the determination of screen brightness data, and as a guide for those who may be interested in developing more suitable instruments.

APPENDIX

Instruments and Procedures for the Measurement of Screen Brightness

This presentation of instrument specifications and procedures for their use in the determination of motion-picture screen brightness has been prepared to provide more definite answers for two questions considered in the previous discussion:

1. What quantities are to be measured, and how are the measurements to be made?

2. What are adequate standards for judging the suitability of instruments?

Essentially the presentation is a formulation of the discussions and experience of the Screen Brightness Committee, although in some matters of detail it has been necessary to infer which of the possibilities is preferred.

The *Proposed Specifications*, presented below, for illumination, brightness, reflectance, and luminous flux meters describe instruments which do not necessarily exist.

---

* This memorandum was prepared before the widespread interest in three-dimensional projection using dual prints and polarized projection light; accordingly the instrument specifications do not include a discussion of apparent brightness for polarized viewers, or of determinations of depolarization. These problems are under study by another subcommittee of the SMPTE Screen Brightness Committee, which will make recommendations on these additional requirements of instrumentation and measurement.

Table I. The Procedures for Measuring Screen Brightness — A Summary of Necessary Assumptions and Desirable Instruments.

Condition	Assumptions	Instruments Applicable*	Procedure†	Notes
I	(1) None.	(1) Brightness meter, audience-type, high sensitivity, Spec. A.	(1) Measure screen brightness as a function of film transmission, of audience placement and of position on the screen.	(1) This information, or its equivalent, is the ultimate basis for screen brightness standardization. It is usually not practical to determine it directly.
II	(1) Effective film transmission known.	(1) Brightness meter, audience-type, high sensitivity, Spec. A.	(1) Measure screen brightness at selected, arbitrary film densities, as a function of audience placement and of position on the screen.	(1) This procedure is recommended for research studies of screen brightness.
III	(1) Effective film transmission known. (2) Nature of transfer characteristic known.	(1) Brightness meter, audience-type, high sensitivity, Spec. A.	(1) Measure brightness of the bare screen and of the shielded screen as a function of audience placement and of position on the screen.	(1) When the nature of the transfer characteristic for the installation being measured is known, then locations of the two ends of the curve determine the complete transfer characteristic.
IV	(1) Effective film transmission known. (2) Transfer characteristic known. (3) Relative brightness known as a function of projection angle and viewing angle.	(1) Brightness meter, audience-type, Spec. B. or (2) Brightness meter, screen-type, Spec. C.	(1) Measure from one location in the audience, determining brightness of the bare screen as a function of position on the screen. (2) Measure from immediately in front of the screen, determining normal brightness of the bare screen as a function of position on the screen.	(1) Calculation of apparent screen brightness as a function of viewing angle usually is not attempted; most frequently the screen is assumed matte, with brightness independent of viewing angle.

V	(1) Effective film transmission known. (2) Transfer characteristic known. (3) Relative brightness known as a function of projection angle and viewing angle. (4) Brightness of any point on the screen directly proportional to normal, incident illumination.	(1) Brightness meter, audience-type, Spec. B; *plus* illumination meter, screen-type, Spec. D. or (2) Brightness meter, screen-type, Spec. C; *plus* illumination meter, screen-type, Spec. D.	(1) Measure from one location in the audience, determining brightness of the bare screen at its center. Measure incident bare-screen illumination normal to the screen as a function of position on the screen. (2) Measure from immediately in front of the screen the normal, bare-screen brightness at its center. Measure incident bare-screen illumination normal to the screen as a function of position on the screen.	(1) This procedure was followed for the 1947 and 1950–51 Theater Surveys. (2) This procedure, or that for condition IV (depending upon instruments available) is the most complete that it is convenient to attempt in an operating theater.
VI	(1) Effective film transmission known. (2) Transfer characteristic known. (3) Brightness of any point on the screen directly proportional to normal, incident illumination.	(1) Illumination meter, screen-type, Spec. D *plus* gonioreflectometer, Spec. E.	(1) Measure incident bare-screen illumination normal to the screen as a function of position on the screen. Measure reflectance of the screen as a function of projection angle and viewing angle.	(1) Measurement of screen reflectance as a function of projection angle and viewing angle is usually attempted only in the laboratory on a sample of the screen material.
VII	(1) Effective film transmission known. (2) Transfer characteristic known.	(1) Illumination meter, screen-type, Spec. D *plus* reflectance meter, Spec. F.	(1) Measure incident bare-screen illumination normal to the screen as a function of position on the screen. Measure normal reflectance of the screen.	(1) This procedure was used as an alternate in the 1950–51 Theater Survey.

Continued on next page

Table I. Concluded.

Condition	Assumptions	Instruments Applicable*	Procedure†	Notes
	(3) Relative brightness known as a function of projection angle and viewing angle.			
	(4) Brightness of any point on the screen directly proportional to normal, incident illumination.			
VIII	(1) Effective film transmission known.	(1) Luminous flux meter, differential-type, Spec. G.	(1) Measure light flux leaving the projection lens, determining independently the flux in individual pencils of light directed to specific locations on the screen as a function of position on the screen.	(1) This is a practical serviceman's procedure for projector adjustment.
	(2) Transfer characteristic known.			
	(3) Relative brightness known as a function of projection angle and viewing angle.			
	(4) Brightness of any point on the screen directly proportional to normal, incident illumination.			
	(5) Screen reflectance known.			

IX	(1) Effective film transmission known. (2) Transfer characteristic known. (3) Relative brightness known as a function of projection angle and viewing angle. (4) Brightness of any point on the screen directly proportional to normal, incident illumination. (5) Screen reflectance known. (6) Distribution of incident illumination over the screen area known.	(1) Luminous flux meter, integral-type, Spec. H.	(1) Measure total light flux leaving the projection lens.	(1) This procedure is suitable for adoption as a routine check by projectionists in any theater.

Notes:
* When there are two types of instruments suitable for a given measurement (within the range of meter types specified in the Appendix) both are listed.
† When alternative instruments have been noted, two procedures are given also, corresponding respectively to the listing of the instruments

It has been the intention to prescribe instruments that are both essential and desirable, attempting to strike a balance between what the Screen Brightness Committee has found necessary and what can reasonably be manufactured. Obviously the more complex research instrument specifications make little concession to ease of manufacture, while the less complex practical instruments have no reason for consideration unless they can be widely available at reasonable prices. In every case it has been necessary to balance the probable use of the data, the magnitude of other measurement errors, and the estimated cost of more stringent specifications. In the opinion of the Committee, these compromises are the most desirable that can now be selected.

It is recognized further that much information has been accumulated and will continue to be obtained — with instruments that do not meet these specifications. This report is not intended to discredit these instruments or data derived with them, but only to provide a standard for their evaluation. By indicating what variables may have influenced the results, and cautioning against unwarranted assumptions and conclusions, these specifications may help to make more useful the data from such nonconforming instruments.

Recommended Procedures for the measurement of illumination, brightness, reflectance, and luminous flux follow the general outline of the Screen Brightness Committee's Theater Surveys. These procedures, it will be noted, are concerned only with the problems of practical theater measurement and not the more complex research activities. The more precise data for controlled studies will be obtained by relatively few workers who are deeply engrossed in the subject, and who will want to work out their own procedures. These recommendations are intended solely for those who must add the measuring of screen brightness to many other problems and interests, and who will use the simpler instruments of necessity; for their use the Recommended Procedures outline what measurements need be made and what instruments are required, plus necessary information on methods of measurement, calculations, and possible interference or complications.

At the beginning of the Committee's Theater Surveys it had been agreed that the measurement of screen illumination — convenient and straightforward — should be depended upon to provide the primary practical data, and that screen brightness should be calculated after determining a reflectance factor for computing brightness. It soon became obvious, however, that in many instances attempts to measure illumination at points on the screen a considerable distance above the stage or ground present real mechanical problems. On the assumption that auxiliary equipment sufficiently universal to position the light-sensitive elements of illumination meters properly in every theater installation will not be common, the Committee has also considered measurements of total luminous flux at the projector, in order to provide data that might otherwise be unobtainable. Finally, this report has been expanded to point out the real objective of screen brightness measurements, together with some of the pitfalls of oversimplification.

Index to Specifications

Index to Recommended Practices

Specification A. Brightness Meter — Audience-Type — High Sensitivity*

1. Purpose. An instrument to measure brightness of a motion-picture screen, for use from the audience, and of adequate sensitivity to measure the range of brightnesses defining the transfer characteristic of projected motion pictures.†

2. Scope. This specification describes a light-sensitive cell which can be located within the audience area to receive the light reflected from a motion-picture screen's surface, a meter to indicate cell output, together with a suitable aiming device so that the brightness can be determined for a specific, small screen area.

3. Useful Range. 0.005–60 ft-L; multiple scales or logarithmic scale required.

4. Accuracy.

a. Initial Accuracy: ±7% of the scale point within the upper half of the scale, and ±7% of the midscale value within the lower half of the scale — measured at 70 F with tungsten light at a color temperature of 2700 K. Scales shall be so chosen that any brightness within the useful range can be read with an initial accuracy of at least ±15%.

b. Temperature Sensitivity: Any change in indication resulting from a temperature change of ±20 F from the reference temperature of 70 F shall not exceed 12%.

c. Fatigue: Negligible, providing cell has not been exposed to illumination in excess of 100 times the measured value within 10 min of measurement.

d. Color Response: The sensitivity shall correspond to the standard luminosity curve, such that the response curve of the cell shall be within that envelope whose ordinates are the standard luminosity curve ±5% of the maximum ordinate.

e. Integration: The meter is intended for use with 48- to 72-cycle illumination,‡ and a net integral shutter transmission of 30% – 70%. If under these conditions there is a frequency error a calibration curve shall be supplied.

5. Response. Meter period and damping shall be chosen to give a response time of less than 10 sec. Meter and cell shall be rugged, and resistant to a shock of 20 g.

6. Acceptance Angle. This meter shall be shielded so that the 50% cutoff from a point source occurs at an acceptance angle no greater than ±0.5°.

7. *Operation.*

a. Convenience: Instrument easily moved, located, and read by one man.

b. Power: Self-contained power would be preferred, although 110-v, 60-cycle, a-c operation may be required.

c. Support: Sufficient for use of meter from the seating area of the auditorium. The supporting and aiming device should indicate viewing angles sufficient to describe the audience positions from which measurements are made.

8. *Probable Range of Values.*

	Indoor Theaters		*Outdoor Theaters*	
	Max.	*Min.*	*Max.*	*Min.*
θ = Horizontal angle subtended by screen from theater midline	53°	9°	35°	6°
ψ = Horizontal viewing angle, to screen normal	±65°	0°	±65°	0°
α = Vertical viewing angle, to screen normal	+45°	−10°	+40°	+2°

Notes

* This meter is intended to provide direct data on the brightness of projected pictures, and therefore must be used for extended periods of measurement to determine the variations in brightness over the picture area and the variations with subject matter. It is primarily a research instrument.

† This meter will also be useful for measuring brightnesses of the screen surround, and of the audience areas of the theater.

‡ Since current practice overwhelmingly favors intermittent projection, the meters for measuring the brightness of motion-picture screens must integrate a series of light pulses. Usually 35mm projection equipment provides 48 pulses/sec, while 16mm projection equipment provides 72 pulses/sec at "sound speed" and 48 pulses/sec at "silent speed." The light pulses are interspersed with almost total darkness; light pulses are of approximately equal duration and are approximately equally spaced in time.

Specification B. Brightness Meter — Audience-Type*

1. *Purpose.* An instrument to measure brightness of a motion-picture screen from the audience area, of adequate sensitivity to measure the brightness of a bare screen.

2. *Scope.* This specification describes a light-sensitive cell which can be located within the audience area to receive the light reflected from a motion-picture screen's surface, a meter to indicate cell output,† together with a suitable aiming device so that the brightness can be determined for a specific, small screen area.

3. *Useful Range.* 0.2–60 ft-L. Multiple scales or logarithmic scale required.

4. *Accuracy.*

a. Initial Accuracy: Same as Spec. A.

b. Temperature Sensitivity: Same as Spec. A.

c. Fatigue: Negligible, providing cell has not been exposed to illumination in excess of 10 times the measured value within 10 min of measurement.

d. Color Response: Same as Spec. A.

e. Integration: Same as Spec. A.

5. *Response.* Same as Spec. A.

6. *Acceptance Angle.* This meter shall be shielded so that the 50% cut-off from a point source occurs at an acceptance angle no greater than ±1.5°.

7. *Operation.* Same as Spec. A.

8. *Probable Range of Values.* Same as Spec. A.

Notes

* This specification describes a meter suitable for measuring screen brightness when the projector is operated normally except that no film is threaded into the gate.

† Committee experience has indicated that it is highly desirable for this instrument to be direct reading; there are several meters available that nearly meet these specifications, but require the subjective balancing of two illuminated fields. In these existing meters, the two fields are usually of different colors and different observers frequently disagree in their choice of balance readings.

Specification C. Brightness Meter — Screen-Type*

1. Purpose. An instrument to measure point-to-point normal brightness of a motion-picture screen, of adequate sensitivity to measure the brightness of a bare screen.†

2. Scope. This specification describes a light-sensitive cell which can be located within a few feet of the screen face to receive the light reflected from a motion-picture screen's surface, a meter to indicate cell output, together with a suitable support to position the cell in the desired location in front of the screen.

3. Useful Range. Same as Spec. B.

4. Accuracy. Same as Spec. B.

5. Response. Same as Spec. A.

6. Acceptance Angle. This meter shall be shielded so that the 50% cut-off from a point source occurs at an acceptance angle no greater than ±35°; it is assumed that the meter will be used at a distance from the screen of 2–3 ft. For meters intended to be used at greater distances, the locus of the 50% cut-off shall enclose a screen area no larger than that permitted above.

7. Operation.

a. Convenience: Instrument easily moved, located, and read by one man.

b. Power: Self-contained power preferred.

c. Support: Support must be portable in a passenger automobile, it must be capable of being assembled and operated by one man, and it must support the cell at any location before the screen without danger of contact or injury to the screen surface.

8. Probable Range of Values. The following table lists the range of variables normally expected. Symbols refer to the drawing in "Recommended Practice for the Determination of Bare-Screen Brightness."

	Indoor Theaters		*Drive-In Theaters*	
	Max.	*Min.*‡	*Max.*	*Min.*‡
H Ft	30	9	52.5	22.5
W Ft§	40	12	70	30
N Ft	10	2	25	10
B_A Ft-L	30	4	20	2
B_C Ft-L	28	1	15	0.5
Reflectance %	100‖	35	80	30
Perforated Screen	Yes		No	

Notes

* This specification describes a meter of general usefulness, comparable in application and results to Specification B except that less information is obtained about the variations in brightness with changes in the viewing angles. The choice between these two meters will probably be made on the basis of availability, convenience and the frequency of occurrence of directional screens.

† This meter's practical usefulness is limited to the measurement of screens that are matte, or nearly perfect diffusers. Its results with directional screens can be interpreted accurately only after careful

calibration with the specific directional screen measured.

‡ The minimum value of brightness quoted in section 8 "Probable Range of Values" assumes low reflectance of the screen combined with measurements in a corner of the screen. If measurements are made at the geometric center, this minimum expected brightness can be increased by 100% or more.

§ These screen widths are based upon a picture aspect ratio of 1.33. At the present time there is consideration of larger aspect ratios at least up to 2.85, which may increase the values of "W" without changing maximum values of "H."

‖ Apparent reflectance values of 100% or more may occur with screens having some directional effect; in the 1951 Theater Survey several screens with apparent brightness gains up to 200% were found.

Specification D. Illumination Meter*

1. Purpose. An instrument to measure point-to-point illumination at the motion-picture screen, and to determine illumination distribution.†

2. Scope. These specifications describe a light-sensitive cell which can be located to intercept light falling on any part of a motion-picture screen's surface, a meter to read cell output located where it can be read by an observer at the base of the screen, and a support to position the cell in the desired place in front of the screen.

3. Useful Range. Low scale, 0.5–30 ft-c. High scale, 2–60 ft-c.

4. Accuracy.

a. Initial Accuracy: Same as Spec. A.

b. Temperature Sensitivity: Same as Spec. A.

c. Fatigue: Same as Spec. B.

d. Color Response: Same as Spec. A.

e. Integration: Same as Spec. A.

5. Response. Same as Spec. A.

6. Operation.

a. Convenience: Instrument easily moved, located, and read by one man.

b. Power: Self-contained power preferred.

c. Support: Support must be portable in a passenger automobile, it must be capable of being assembled and operated by one man, and it must support the cell at any point on the screen without danger of contact or injury to the screen surface. (If the support holds the cell at an appreciable distance forward of the screen, an inverse square law correction will need to be made on illumination values.)

7. Probable Range of Values. The following table‡ lists the range of variables normally expected. Symbols refer to the drawing in "Recommended Practice for the Determination of Bare-Screen Brightness."

	Indoor Theaters		*Drive-In Theaters*	
	Max.	*Min.*	*Max.*	*Min.*
H Ft	30	9	52.5	22.5
W Ft§	40	12	70	30
N Ft	10	2	25	10
E_A Ft-c	40	5	27	2.7
E_C Ft-c	37	1.3	20	0.7
Reflectance	100	35	80	30
Perforated Screen	Yes		No	

Notes

* This is considered the basic instrument for the practical measurement of projection conditions in the theater. At the present stage of instrument development, it appears that this instrument is most likely to be the one generally available.

† This specification describes a meter suitable for measuring screen illumination only. The Screen Brightness Committee, however, has indicated that eventually

some meter for measuring the illumination of the screen surround will be necessary in order to control picture perception. This meter plus that described in Spec. A are the only two appropriate — and this meter could be used only if its Useful Range could be extended to 0.01–60 ft-c. There is a slight advantage in measuring surround illumination rather than surround brightness, because most of the screen surround makes use of surfaces of low reflectance — and therefore measurements of illumination do not require as great sensitivity to low signal.

‡ This table is a restatement of the corresponding table in Spec. C, revised to give approximate illumination values instead of brightness values.

§ These screen widths are based upon a picture aspect ratio of 1.33. At the present time there is consideration of larger aspect ratios at least up to 2.85, which may increase the values of "W" without changing maximum values of "H."

Specification E. Gonioreflectometer*

1. Purpose. An instrument to measure specular reflectance† of motion-picture screens as a function of viewing angle, for use in conjunction with measurements of illumination.

2. Scope. This specification describes a light-sensitive element receiving light reflected from the screen, a standard source illuminating the screen (or provision to use a standard projector), a meter indicating response of the light-sensitive element, together with a mechanism for holding these components in proper relationship and indicating their relative angles.

3. Useful Range. Reflection factor 0.01 to 10.‡

4. Accuracy.

a. Initial Accuracy: Same as Spec. A.

b. Temperature Sensitivity: Same as Spec. A.

c. Fatigue: Same as Spec. A.

d. Color Response: Same as Spec. A.

e. Integration: If the meter is designed to provide its own standard source of illumination the source may be continuously excited and no intermittency problem results. If on the other hand the meter uses the light from a standard projector, its integration performance should be the same as Specification A.

f. Measuring Illumination. Reflectance shall be measured with light of a quality approximating a color temperature of 2700°K., or with light of high-intensity arc quality.

5. Response. Same as Spec. A.

6. Field of View.

a. Measuring Illumination: The incident illumination shall be specular, with the light confined to a cone of not more than ±0.5° included angle.

b. Acceptance Angle: The light-sensitive cell shall be shielded so that the 50% cut-off from a point source occurs at an acceptance angle no greater than ±0.5°.

c. Area Measured: The screen surface measured for reflectance shall be greater than 0.2 sq ft but less than 4 sq ft.

7. Angle of Reflection. The light-sensitive element shall be adjustable to measure reflectance through the range of illumination angles in section 9 of this specification and of viewing angles in section 8 in Spec. A.

8. Operation.

a. Convenience: Same as Spec. D.

b. Power: Self-contained power is preferred. If necessary for the proper balance of performance and portability to use external power (for example to provide a self-contained source of illumination) an instrument operating on 110-v, a-c–d-c can be used.

c. Support: Since it will be sufficient to measure reflectance at a limited number of locations on the screen, it will not be necessary to cover the full range of screen area required for Spec. D. It would be a convenience in many cases, however, to use the same support therein described.

9. Probable Range of Values. Same as Specs. A and C, plus:

	Max.	*Min.*
ϕ_V = Vertical projection angle	±25°	0°
ϕ_H = Horizontal projection angle	± 5°	0°

Notes

* There are two possible use patterns for a motion-picture screen gonioreflectometer: Measurement in the theater, and measurement in the laboratory. In either event it is expected that this will be primarily a research instrument, and that there will never be a great number constructed. At present it seems more likely that the laboratory usage is the more probable, and in this case the requirements that have to do primarily with portability (section 8 of this specification) can be disregarded. No other distinction between the two use patterns seems desirable.

† Specular Reflectance is important for motion-picture screen performance because for any one position on the screen, the base of the incident light cone is the exit pupil of the projection lens, and the base of the reflected light cone is circumscribed around the observer's eyes at any one viewing position. (Diffuse reflection is only useful as an approximation, when the screen surface is nearly matte and no investigation is made of angular distribution.

‡ A wide range of reflectance values may be expected. For matte screens there is variation from the low values of deteriorated screen surfaces, through the medium values of the weather-resistant surfaces of outdoor theaters, to the high values of new indoor screens. For directional screens there is variation from the very low values of off-angle reflection to the very high values in the direction of maximum efficiency.

Specification F. Reflectance Meter*

1. Purpose. An instrument to measure normal reflectance of motion-picture screens, for use in estimating brightness from measurements of illumination. Usefulness of this instrument is practically confined to the measurement of matte screens.†

2. Scope. This specification describes a light-sensitive element receiving light reflected from the screen, a standard source illuminating the screen, a meter indicating response of the light-sensitive element, together with a mechanism for holding these components in proper relationship.

3. Useful Range. 30–120% reflectance.

4. Accuracy. Same as Spec. E.

5. Response. Same as Spec. A.

6. Field of View.

a. Measuring Illumination: The incident illumination shall be specular, with the light confined to a cone of not more than ±1.5° included angle.

b. Acceptance Angle: The light-sensitive cell shall be shielded so that the 50% cut-off from a point source occurs at an acceptance angle not greater than ±1.5°.

c. Area Measured: The screen surface measured for reflectance shall be greater than 0.2 sq ft but less than 4 sq ft.

7. Angle of Reflectance. The light illuminating the screen shall be normal to its surface. The angle between the light-sensitive element and the normal to the center of the test area shall be approximately 10°.‡

8. Operation. Same as Spec. E.

9. Probable Range of Values. Same as Spec. E.

Notes

* In contrast to the gonioreflectometer of Spec. E, this instrument is intended almost exclusively for use in the theater. Therefore, the requirements for portability, etc. cannot be compromised.

† It would be possible to study a particular motion-picture screen with more refined equipment to obtain a calibration so that this particular instrument's readings could be converted to a complete specification of angular response. The difficulties of this task, however, make it desirable to confine this meter to screens that may be considered diffuse scatterers.

‡ It would be a convenience if this instrument could measure interchangeably both the specular reflectance specified, and the total diffuse reflectance from the same light source. With such an instrument the two reflectances could be compared to indicate immediately when the screen was matte or directional.

Specification G. Luminous Flux Meter — Differential-Type*

1. Purpose. An instrument to measure luminous output at the projector, and to indicate the relative intensities of the pencils of light directed to specific locations on the screen. This meter is intended for use primarily when physical conditions and the instruments available prevent measurements at the screen.†

2. Scope. This specification describes a light-sensitive cell which can be located to intercept the total luminous output from the projection lens (or a predetermined portion of that total output), a meter to read cell output, and any necessary appurtenances for their use. Specifically included are necessary masks or other devices to be inserted into the projector aperture and focused on the screen,‡ in order to sample particular screen areas for measurement of light flux. This meter will be used either immediately at the lens exit within the projection booth, or immediately beyond the projection port just outside the projection booth.

3. Useful Range. 100–20,000 lumens§ multiple scales or logarithmic scales required.

4. Accuracy. Same as Spec. A.

5. Response. Same as Spec. A.

6. Scanned Area. As a minimum the meter must read luminous flux to each of the five measuring areas specified in "Recommended Practice for the Determination of Bare-Screen Brightness." Each pencil shall intercept at the screen no more than 1% of the illuminated screen area.

7. Operation.

a. Convenience: Instrument easily moved, located, and read by one man.

b. Power: Self-contained power preferred. 110-v, a-c will be available, however.

c. Support: In all cases the instrument and any supporting structures must be portable in a passenger automobile, transportable through a projection-room door, and it must be capable of being assembled and operated by one man. When intended for use within the projection booth any support must not interfere with the projector mechanism, or be limited by the front wall or port of the booth. When intended for use outside the projection booth, suitable support for the instrument to position it firmly will probably be required.

8. Probable Range of Values. The following table lists the range of variables normally expected. Symbols refer to the drawing in "Recommended Practice for the Measurement of Luminous Flux."

Value		Indoor and Outdoor Theaters Max.	Min.
D	In.	4.00	2.03
S	In.	24	6
2α	Degrees	24°	5°
F	Lumens total flux	20,000	200
N	Ft	20	2

Notes

* This meter is relatively simple in operation and probably such that a regular projector serviceman could include it in his kit. There is much to be gained by research studies of screen brightness, but perhaps equally important is the practical gain from proper servicing of equipment; convenient measurement is a prerequisite for adequate servicing.

† Screen brightness and illumination are considered functions of the *masked area of the screen,* whereas this meter measures in terms of the *total illuminated area.* Any significant difference between masked and total area must be noted, because it will affect not only the total flux transmitted, but also the relative positions of the measuring areas sampled from the total screen.

‡ A standard projector aperture is assumed. Any departure from this standard must be noted.

§ These values of luminous flux are mean net values, integrated over a sufficient time to damp out the flicker of intermittent projection.

Specification H. Luminous Flux Meter — Integral-Type*

1. Purpose. An instrument to measure total luminous output at the projector when physical conditions prevent measurements of intensity and distribution at the screen. Because of the failure to provide some of the important data, this meter and method of measurement are proposed only to provide some information when otherwise there would be none available.†

2. Scope. These specifications describe a light-sensitive cell which can be located to intercept the total luminous output from the projection lens (or a truly representative portion of that total output),‡ a meter to read cell output, and any necessary appurtenances for their use. This meter will be used either immediately at the lens exit within the projection booth, or immediately beyond the projection port just outside the projection booth.

3. Useful Range. 1000–20,000§ lumens.

4. Accuracy. Same as Spec. A.

5. Response. Same as Spec. A.

6. Operation. Same as spec. G.

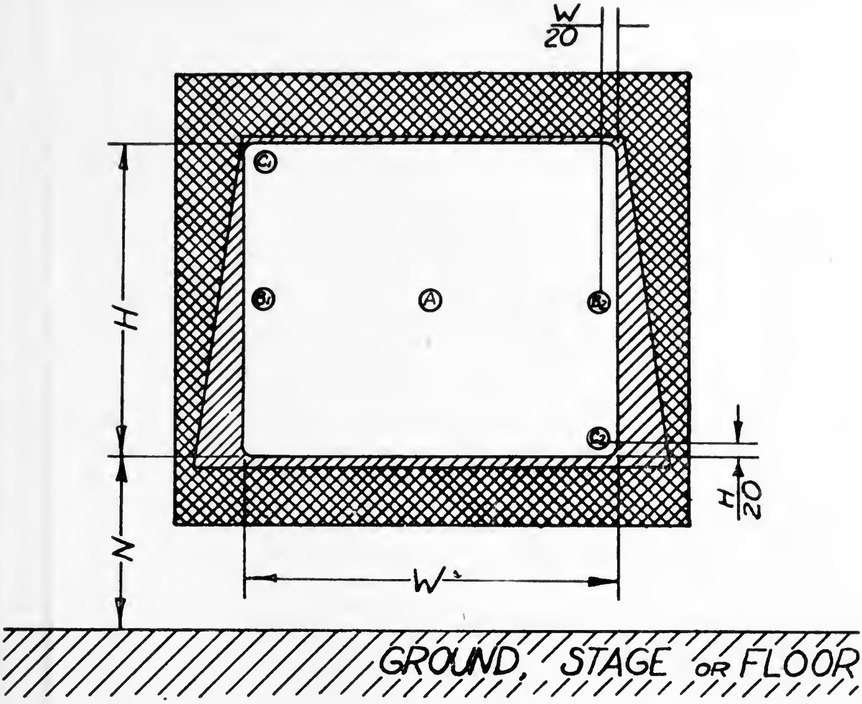
Notes

* This meter is one of the most simple for control of screen brightness. It would be desirable to have this an inexpensive instrument available in all the better projection rooms.

† Screen brightness and illumination are considered functions of the *masked area of the screen,* whereas this meter measures *total illuminated area.* Any significant difference between masked and total area must be noted.

‡ A standard projector aperture is assumed. Any departure from this standard must be noted.

§ These values of luminous flux are mean net values, integrated over a sufficient time to damp out the flicker of intermittent projection.



I. Purpose

This procedure describes practical methods for the determination of screen brightness when it is convenient to obtain data on screen illumination. Limitations on instruments commonly available make this indirect method the most generally useful for measurements in the theater.

There are three parts to the procedure: (1) Determination of illumination and illumination distribution, (2) Determination of screen reflectance, and (3) Determination of screen brightness at one selected point. Determination of brightness and brightness distribution relies upon the data of (1) plus that of either (2) or (3).

II. Measurement of Illumination

A. *Description.* This procedure gives a satisfactory measure of screen illumination for the average theater, with the projection system in good adjustment. It describes the determination of screen illumination and its variation over the screen surface, together with the calculation of total effective luminous output of the projector. It is assumed that these data will be basic for any theater evaluation of projection viewing conditions.

B. *Meter Specification.* D

C. *Data.* The projector and light source should be operated normally, with no film in the gate.

1. Measure H and W — the height and average width of the masked area.

2. Note whether there is any pronounced variation in color of illumination across the screen.*

3. Read illumination on the screen in ft-c at positions A, B_1, B_2, C_1, and C_2, using a meter that conforms to "Specification D. Illumination Meter."

4. If E_{B_1} varies from E_{B_2} by more than 50%, or E_{C_1} varies from E_{C_2} by more than 50%, the illumination is sufficiently unbalanced that calculated results will be approximate only.*

D. *Calculations.*†

5. Illuminated Screen Area: Area in square feet = S = H × W.

6. Screen Light Distribution: Side-center ratio $= R_s = \frac{E_{B_1} + E_{B_2}}{2} \times \frac{1}{E_A}$.

Corner-center ratio $= R_c =$

$$\frac{E_{C_1} + E_{C_2}}{2} \times \frac{1}{E_A}$$

7. Total Screen Lumens:‡

$E_A \times 2 =$

$E_{B_1} + E_{B_2} =$

$\frac{1}{2}(E_{C_1} + E_{C_2}) =$

Total

Weighted Average $= F = \frac{1}{5}$ (Total)

Screen Lumens $= F \times S$

E. *Notes*

* If the light beam is decentered, the distribution is poorly chosen, or the equipment is in maladjustment, then the data will indicate how the theater was operating, but it will be difficult to draw other valid conclusions. Variations in color of screen light usually indicate that the optical system components are out of position. Unbalance, as defined in C section 4 usually indicates poor centering, in which case E_A will not be the maximum illumination, and the weighting factors for total flux will not be correct.

† If the projector has a nonstandard aperture, or if the illuminated area is significantly larger than the masked screen area, then the useful screen lumens may be appreciably less than the total projector output. Excessive masking will also tend to improve light distribution because the fall-off becomes more rapid at the edge of the aperture. Significant differences between lighted area and screen area may be expected when projection angles are steep — unless this problem is concealed by the use of a nonstandard, trapezoidal aperture.

‡ The weighting factors in section 7 recommended for estimating total screen lumens from the 5-point measurements may be corrected slightly as more data are analyzed.

III. Measurement of Reflectance

A. *Description.* This procedure will measure screen reflectance for screens which are essentially matte.* In general it is intended to permit use of less expensive and sensitive instruments, which therefore may need more light on the screen than is supplied by a projection beam — perhaps requiring an auxiliary light source up close to the screen and meter. Constancy of reflectance over the screen surface is assumed.† The data are intended for use in calculating screen brightness from screen illumination.

B. *Meter Specification.* F

C. *Data.*

1. Examine the screen for qualitative evidence of nondiffuse reflection, and of variation in reflectance over the screen surface.‡

2. Measure reflectance at one point on the screen (preferably the geometric center if convenient).

D. *Calculations.*

3. ρ = Apparent Reflectance,§ measured in 2 above.

E. *Notes*

* For matte screens which are essentially perfect diffusers, readings of the Reflectometer Specification F indicate the screen reflectance reasonably well. Because this reflectance is a constant independent of viewing angle, the value is applicable for estimating brightness as

perceived from any audience position. If the screen does not approximate a perfect diffuser, then the determination of reflectance is much more laborious.

† Screen Reflectance as herein considered is an integrated value. It is based upon a section of screen small enough to be convenient to measure, and in practice to have constant illumination, but large enough to average the perforated and nonperforated areas of the screen.

‡ Although substantially diffuse reflectance constant over the whole screen is a prerequisite and is frequently assumed (and this is consistent with most of the data from the Theater Survey) there is indication that controlled-reflection screens will become more numerous. For such screens it is essential that one determine reflectance as a polar function of viewing angle. Visual inspection or a simple check with the meter described in this Procedure will detect any wide departure from the usual reflectance pattern. Data from such screens should be clearly identified so that the results are not misinterpreted.

§ The screen property measured is more properly called "Apparent Reflectance," because it is the ratio of the brightness of the screen as seen at a given viewing angle, to the brightness of a perfect diffuser illuminated with the same incident flux. The foot-lambert unit of brightness is so defined that a perfect diffuser illuminated by a flux of 1 ft-candle has an apparent brightness in any direction of 1 ft-lambert.

Therefore

$$\rho = \text{Apparent Reflectance} = \frac{B}{E} = \frac{\text{Brightness}}{\text{Illumination}}$$

IV. Measurement of Brightness

A. *Description.* This method is to be used when a Brightness Meter is available, of adequate sensitivity and response. Brightness is measured when the screen is illuminated by the projection light.

B. *Meter Specification.* B* or C†

C. *Data.*

1. Examine the screen for qualitative evidence of nondiffuse reflection and of variation in reflectance over the screen surface.‡

2. Measure Screen Brightness at one point on the screen (preferably the geometric center)† using a meter that conforms to Spec. B or Spec. C.

3. Measure Screen Illumination at the same point, within 1 min or less to minimize light fluctuations, using a meter that conforms to "Specification D. Illumination Meter."

D. *Calculations.*

4. ρ_A = Apparent Reflectance§ at A

$$\rho_A = \frac{B_A}{E_A} = \frac{\text{Brightness at A}}{\text{Illumination at A.}}$$

E. *Notes*

* If a meter of Type B is available, it would be possible to complete the measurement of brightness distribution using only this instrument and reading directly.

† Meters of Type C measure the integrated brightness over so large an area that measurements made near the screen border are frequently in error because the meter "sees" the dark border. Consequently in order to provide distribution data, the distribution of illumination (Part II) is relied upon to indicate the distribution pattern of brightness too.

‡ This procedure in this simplified form is intended only for matte screens, approximating perfect diffusers. Also see Part III, Note ‡.

§ See Part III, Note §.

V. Calculation of Brightness and Brightness Distribution

A. *Description.* This calculation is intended to give values of bare screen brightness for determining conformance to ASA Standard PH22.39-1952, for determining the side-center and corner-center brightness distributions, and for estimating the adequacy of picture viewing conditions.

B. *Prerequisites.* It will be necessary first to complete Part II and either

Part III or Part IV of this procedure.

C. *Data.*

1. Illumination at the specified points (from Part II)

E_A, E_{B_1}, E_{B_2}, E_{C_1}, and E_{C_2}

2. Apparent Reflectance (from Part III or IV)

ρ_A (or ρ_C if only this can be measured conveniently)*

D. *Calculations.*

3. B_A = Brightness of screen at A† = $\rho \times E_A$ = (Apparent Reflectance) × (Illumination at A).

4. $B_{B_1} = \rho \times E_{B_1}$, etc.

5. V_s = side-center ratio‡ = $\dfrac{B_{B_1} + B_{B_2}}{2} \times \dfrac{1}{B_A}$. V_c = corner-center ratio‡ = $\dfrac{B_{C1} + B_{C2}}{2} \times \dfrac{1}{B_A}$.

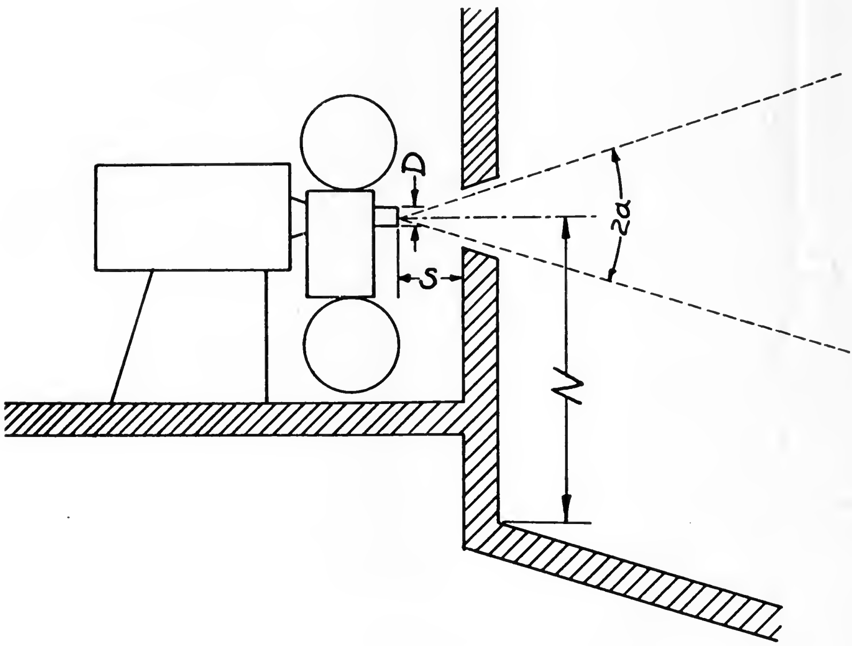
E. *Notes*

* It is assumed in this procedure that ρ = Apparent Reflectance, is constant over the whole screen surface, and is independent of viewing angle.

† This center brightness is the only quantity specified in ASA Standard for Screen Brightness PH22.39-1952.

‡ It will be apparent that since the screen is assumed to be a perfect diffuser, these brightness ratios will be numerically equal to the illumination ratios calculated in Part II.

Recommended Practice for the Measurement of Luminous Flux



I. Purpose

This procedure describes a method of determining the total luminous output of the projector when it is inconvenient or undesirable to obtain data at the screen (cf. "Recommended Practice for the Determination of Bare-Screen Brightness"). From the measurement of Luminous Flux it is possible to check projector alignment and operation. With certain assumptions it is also possible to estimate screen brightness. This procedure will be most useful for projector adjustment and repair, and for checking the constancy of projector performance.

In some of the larger outdoor theaters and in a few indoor theaters, screen size and construction makes it extremely difficult to support a brightness or illumination measuring cell at many of the specified locations at the screen surface (cf. Instruments of Spec. C or D). This procedure therefore fills the need of supplying some "screen brightness" data when otherwise none would be available. Measurements are made with the projector and light source operated normally, except that no film is run through the gate.

Measurements of Luminous Flux can be made with meters of Specification G or H. When estimates of screen brightness are desired, measurements should be made with the Type G; since meters of Specification H do not indicate the variation in illumination intensity over the screen area, and only average illumination can be determined. To determine conformance to the Screen Brightness Standard ASA PH22.39-1952, center brightness must be known.

II. Measurement of Illumination: Meter Type G

A. *Data.*

1. Focus the projector normally on the screen. Examine screen for qualitative evidence of nonsymmetrical lighting, abnormal distribution, or variation in color of illumination.*

2. Measure total luminous flux leaving the projection lens.

3. Insert masks in projection aperture† and measure relative illumination to each of the 5 locations included in "Recommended Practice for the Determination of Bare-Screen Brightness."

B. *Calculations.*

4. *Total Screen Lumens:* read directly from 2 above.

5. *Center Screen Illumination:* read directly from 3 above with the mask corresponding to position "A."

6. *Screen Light Distribution:* calculated from the readings of 3 above.

Side-Center Ratio $R_s = \dfrac{E_{B_1} + E_{B_2}}{2} \times \dfrac{1}{E_A}$

Corner-Center Ratio $R_c =$

$$\frac{E_{C_1} + E_{C_2}}{2} \times \frac{1}{E_A}$$

7. *Average Screen Illumination:* calculated from the readings of 3 above, using the weighting factors given in Part II, Section D-7, of "Recommended Practice for the Determination of Bare-Screen Brightness.

8. *Screen Brightness*‡: Brightness corresponding to the illumination values of 5, 6, and 7 above can be calculated by the method of Part V "Recommended Practice for the Determination of Bare-Screen Brightness" providing that reflectance has been measured or is known.

C. *Notes*

* This procedure will determine satisfactorily the total luminous output of the projector. If the system is in good adjustment this value has significance. If the light beam is decentered, the distribution is poorly chosen, or the equipment is in maladjustment, however, the results will be difficult to interpret. Nonsymmetrical lighting is wasteful of light, poorly chosen distribution impairs either total illumination or picture quality, color variations in illumination usually result from poor positioning of the optical system components.

† These measurements relate to the standard projector aperture. If the aperture is nonstandard, or if the illuminated area overlaps the screen border significantly, these data on total output may not reflect properly the useful light directed to the picture area of the screen.

‡ Inasmuch as the present Screen Brightness Standard specifies only the brightness as the center of the screen without mention of distribution, it will be necessary to calculate center brightness to determine conformance to standards. Average brightness has not been standardized.

III. Measurement of Luminous Flux: Meter Type H

A. *Data.*

1. Focus the projector normally on the screen. Examine screen for qualitative evidence of nonsymmetrical lighting or abnormal distribution.*

2. Measure total luminous flux leaving the projection lens.†

B. *Calculations.*

3. Total Screen Lumens: are read directly.

4. Average Screen Illumination: can be calculated if the illuminated area is measured.

5. Average Screen Brightness‡ corresponding to the average illumination of 4 above, can be calculated by the method of Part V "Recommended Practice for the Determination of Bare-Screen Brightness" providing that reflectance has been measured or is known.

C. *Notes*

* This procedure will determine satisfactorily the total luminous output of the projector. If the system is in good adjustment this value has significance. If the light beam is decentered, the distribution is poorly chosen, or the equipment is in maladjustment, however, the results will be difficult to interpret. Nonsymmetrical lighting is wasteful of light, poorly chosen distribution impairs either total illumination or picture quality, color variations in illumination usually result from poor positioning of the optical system components.

† These measurements relate to the standard projector aperture. If the aperture is nonstandard, or if the illuminated area overlaps the screen border significantly, these data on total output may not reflect properly the useful light directed to the picture area of the screen.

‡ Inasmuch as the present Screen Brightness Standard specifies only the brightness at the center of the screen without mention of distribution, it will be necessary to calculate center brightness to determine conformance to standards. Average brightness has not been standardized.

References

1. F. B. Berger, "Characteristics of motion picture and television screens," *Jour. SMPTE, 55:* 131–146, Aug. 1950.
2. Ellis W. D'Arcy and Gerhard Lessman, "Objective evaluation of projection screens," presented on April 22, 1952, at the Society's Convention at Chicago.
3. W. W. Lozier, "Report of the Screen Brightness Committee," *Jour. SMPTE, 57:* 238–246, Sept. 1951.
4. F. J. Kolb, Jr., "The scientific basis for establishing brightness of motion picture screens — a discussion of screen brightness," *Jour. SMPTE, 54:* 433–442, Apr. 1951.

Proposed Revision, PH22.58 and PH22.59 Apertures for 35mm Projectors and Cameras

Proposed revisions of two American Standards are published on the following pages for three-month trial and criticism. All comments should be sent to Henry Kogel, SMPTE Staff Engineer, prior to January 15, 1954. If no further revisions are recommended, the two proposals will then be submitted to ASA Sectional Committee PH22 for further processing as American Standards.

While these two standards on projector and camera apertures, PH22.58 and PH22.59, deal only with the old 1.33 aspect ratio, it is nonetheless important that they be kept on the books and brought up to date because large segments of the motion-picture industry, both at home and abroad, are still making and projecting motion pictures in accord with these standards. In addition all motion pictures made for television are based upon them.

An earlier proposed revision of the projector aperture standard was published for trial and comment in the June 1953 *Journal* and it is instructive to repeat the accompanying explanatory introduction.

"In reviewing PH22.58, the Film Projection Practice Committee came to the conclusion that the camera centerline should be deleted as well as dimension H which specified the 6-mil differential between camera and projector centerlines. The 6-mil differential was originally inserted to make allowance for film shrinkage so that the release print, after shrinking its normal amount, would have the image centered in the projector aperture. The decrease in the shrinkage characteristic of film eliminates the need for this differential, and now permits the use of the projector aperture centerline for both the projector and camera. In addition, the corner radius has been decreased to be in accord with present practice of essentially square corners."

It is obvious that camera and projector aperture standards are completely interdependent and the two should have been processed simultaneously. Had this been done, the values of E and F in both standards would probably have been modified by the amount of the shift in the camera aperture centerline. On the authorization of Henry Hood and Glenn Dimmick, Engineering Vice-President and Standards Committee Chairman, respectively, these changes have now been incorporated in both draft revisions.

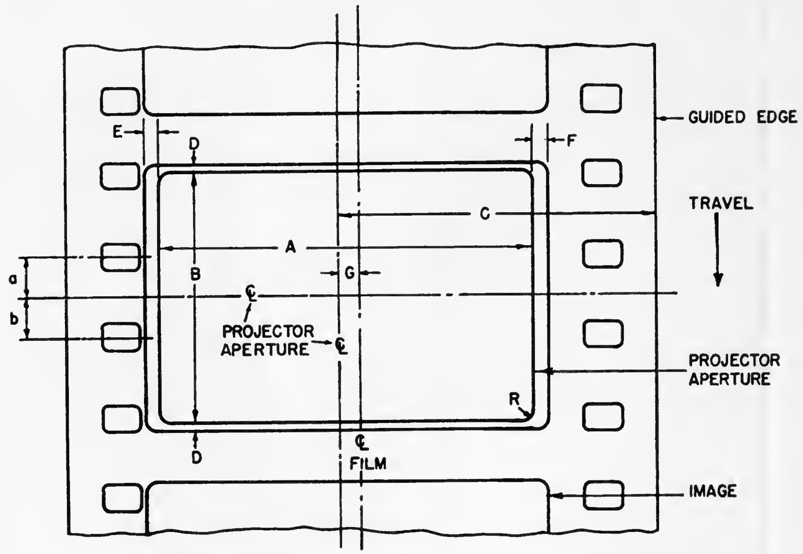
It should be noted in this first publication of PH22.59, as revised from the earlier Z22.59-1947, that the values of C, E and F have been altered by 6 mils and that the title has been slightly modified. The value of dimension F, of course, affects the space available for the sound record, as specified in American Standard Z22.40-1950. The possibility of conflict on this score should be given consideration in your critical review of these standards.—*H.K.*

Proposed American Standard

Aperture for 35mm Sound Motion-Picture Projectors

Second Draft

PH22.58
Revision of Z22.58–1947



Dimension	Inches	Millimeters
A	0.825 ± 0.002	20.95 ± 0.05
B	0.600 ± 0.002	15.25 ± 0.05
C	0.738 ± 0.002	18.74 ± 0.05
D	0.0155	0.394
E	0.022	0.56
F	0.021	0.53
G	0.049	1.24
R	Not > 0.005	Not > 0.13
a = b = ½ longitudinal perforation pitch.		

These dimensions and locations are shown relative to unshrunk raw stock.

Note: The aperture dimensions given result in a screen picture having a height-to-width ratio of 3 to 4 when the projection angle is 14 degrees.

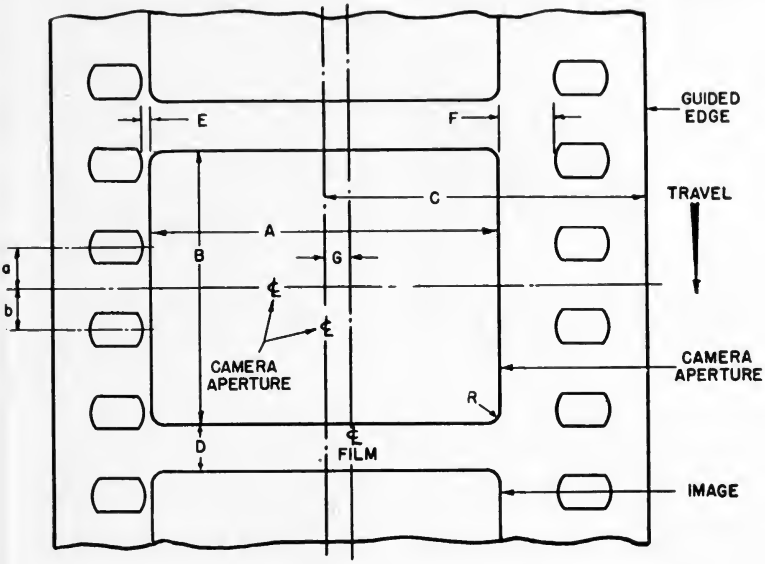
NOT APPROVED

Proposed American Standard

Aperture for 35mm Sound Motion-Picture Cameras

First Draft

PH22.59
Revision of Z22.59-1947



Dimension	Inches	Millimeters
A	0.868 ± 0.002	22.05 ± 0.05
B	0.631 ± 0.002	16.03 ± 0.05
C	0.738 ± 0.002	18.75 ± 0.05
D	0.117	2.97
E	0.016	0.38
F	0.115	2.92
G	0.049	1.24
R	0.03 Approx.	0.76 Approx.
a = b = ½ longitudinal perforation pitch.		

These dimensions and locations are shown relative to unshrunk raw stock.

Note: The aperture dimensions given in combination with an 0.600 × 0.825 in. (15.25 × 20.95 mm) projector aperture result in a screen picture having a height-to-width ratio of 3 to 4 when the projection angle is 14 degrees.

NOT APPROVED

Engineering Activities

American Standards on Photographic Rolls and Sheets

Below are listed the numbers and titles of recently approved American Standards in the field of still photography. These may be ordered from the American Standards Association, 70 E. 45 St., New York 17, N.Y. Additional listings of such standards will be published in the *Journal* from time to time, as they are made available, as a service to those readers who maintain an active interest in still, as well as motion-picture, photography.

"Photographic Paper Rolls," PH1.11-1953. (Revision of Z38.1.5-1943 and Partial Revision of Z38.1.6-1943)

"Photographic Paper Sheets," PH1.12-1953. (Revision of Z38.1.43-1947 and Partial Revision of Z38.1.6-1943)

British Standards

Three British Standards and one draft standard have been received at the Society Headquarters and are listed below.

BS 586:1953. Photo-Electric Cells of the Emission Type for Sound Film Apparatus.

BS 1404:1953. Screen Luminance (Brightness) for the Projection of 35Mm Film.

BS 1988:1953. Measurement of Frequency Variation in Sound Recording and Reproduction.

CR (ACM) 3896. Draft Recommendations for Determining and Expressing the Performance of Loud Speakers by Objective Measurements.

Loan copies of the above are available upon request.—*Henry Kogel*, Staff Engineer.

Book Reviews

Principles of Color Photography

By Ralph M. Evans, W. T. Hanson, Jr., and W. Lyle Brewer. Published (1953) by John Wiley & Sons, 440 Fourth Ave., New York 16, N.Y. i–xi + 672 pp. + 21 pp. bibliography + 15 pp. index. 324 illus. 6 × 9 in. Price $11.00.

Some of the best scientific reference books have been written by research workers who suddenly have become engaged in a subject and find that no authoritative text exists to give them an overall picture of the fundamental principles of that subject. In the course of reading hundreds of original papers and slowly fitting the essential facts and concepts together, the thought occurs how much easier the task would be if a reference work were available, containing the necessary background data required for investigating the subject further.

Apparently the authors of this book experienced such thoughts, especially Evans and Hanson, who recall in the preface the need that existed in the early years of Kodachrome for an exhaustive treatment of the actual basis on which processes of color photography had been and were being developed. In 1938, three years following the introduction of 16mm Kodachrome, they began the preparation of the present text. World War II and increased responsibilities afterwards made the completion of the book difficult, and so Mr. Brewer was enlisted in 1946. Mr. Brewer spent practically full time for several years in bringing the book to its final state. This gives one an idea of the comprehensive nature of the book and a fuller understanding of the tremendous amount of effort involved in writing a book in a field where no similar one existed before.

To a very large extent the book is an organized compilation of previously published material. However, much unpublished original work is included, also. There are 18 chapters, with the following titles: Response of the Eye to Light in Simple Fields; Systems of Color Specification and Measurement; Responses to Light in Complex Fields; Visual Processes and Color Photography; Response of Photographic Materials; Color Response of Photographic Materials; Photographic Formation of the Color Image; Color Photographic Systems; Types of Dyes and Other Colorants; Optical Characteristics of Colorants in Combination; Measurement of Density; Color Sensitometry; Analyses of Color-Sensitometric Characteristics; Reproduction Characteristics of a Hypothetical Subtractive Color Process; Duplicating; Copying a Color Photograph; Color Reproduction Theory for Additive Photographic Processes; and Color Reproduction Theory for Subtractive Photographic Processes. An extensive bibliography, author index and subject index complete the book.

Mathematics is used freely throughout the text wherever the subject material is amenable to such treatment. The authors state that they attempted to word the text so that a careful study of the mathematical steps would not be required for an understanding of the principles and conclusions reached. Their attempt in this has not been too successful, in the opinion of the reviewer, but it is probably as close to success as could be expected without an extensive expansion of the present book. Perhaps if the discussions on certain subjects which have no place in the book had been eliminated, it would have been possible to give a fuller development of the mathematical steps. Chapter V, for example, on the response of photographic materials, which takes over 50 pages, is certainly out of place, and anyone qualified to read the rest of the book will ignore it. There are at least another 200 pages in the book that will be regarded as "filler" by the audience for which the book is intended.

Except for the above general criticism, the book is extremely well done. It presents a thorough analysis of the problems involved in color reproduction theory and shows to what extent practical processes have approached ideal solutions. Color sensitometry and color densitometry are treated in a very lucid style. Interimage effects are nicely described and mathematically correlated with practice. The wealth of experimental data and the numerous computations are almost overwhelming at times. The chapters, from chapter seven through chapter eighteen, will be of greatest interest to most experienced photographic color technologists. These chapters contain the bulk of the new material presented in the book, but the going gets rough in spots if one's knowledge of determinants and matrices is rusty. There is no doubt but that this book should become a part of every technical reference library and should be owned personally by every color technologist.—*Lloyd E. Varden*, Technical Director, Pavelle Color Inc., 533 W. 57 St., New York 19, N.Y.

New Screen Techniques

Edited by Martin Quigley, Jr. Published (1953) by Quigley Publishing Co., 1270 Sixth Ave., New York 20, N.Y. 208 pp. 71 illus. 6 × 9 in. $4.50.

This potpourri of 26 illustrated articles is divided into two parts: Part I deals with the production and exhibition of stereoscopic motion pictures; Part II covers similar material in relation to the Cinerama and CinemaScope wide-screen systems.

Of the ten stereo articles in Part I, four are worthy of note: "Polaroid and 3-D Films" by William H. Ryan; "Basic Principles of 3-D Photography and Projection" by John A. Norling; "The Stereo Window" by Floyd A. Ramsdell; and "3-D in Theatres" by James Brigham. Concise, factual, they give the reader a good, basic background in stereocinematography. A fifth article, "3-D in Europe" by Frank A. Weber, a report on current stereo activity abroad, may be of interest to many since so little has been written on the subject. This reviewer took particular exception to "What Is Natural Vision" by Milton L. Gunzburg, because the article never quite got around to explain or support Natural Vision's adoption of the fixed interaxial, variable convergence system, giving over instead a great deal of effort to deride proponents of other systems.

The second half of the book has less of value to offer than the first. With the exception of "Adding Sound to Cinerama" by Hazard E. Reeves, "Sound for CinemaScope" by Lorin D. Grignon and "The Anamorphoser Story" by H. Sidney Newcomer, most of the material is devoted to general background and personalities rather than to the processes themselves.

While this collection cannot be recommended as a source of information for engineers, it may well be of topical interest to many in our industry who want to be in touch in a general nontechnical way with developments in the stereoscopic field. It must be assumed that this is the audience for which the book was intended.—*Arnold F. T. Kotis*, Stereo Consultant, 3937 49 St., Sunnyside, L.I., N.Y.

Television Advertising and Production Handbook

By Irving Settle, Norman Glenn and Associates. Published (1953) by Thomas Y. Crowell, 432 Fourth Ave., New York 16, N.Y. i–xv + 356 pp. + 109 pp. appendix + 11 pp. index. Numerous illustrations, diagrams and plates. $6.00.

By unfreezing over six hundred television channels in the VHF bands and over fourteen hundred in the UHF bands, the FCC has given impetus to the construction and operation of hundreds of new television stations in the near future. Thousands of applications will be made for construction permits and eventually hundreds will be granted with the ultimate aim of having at least one television station in every city, large or small, in the United States and its possessions. Added to this will be hundreds of firms supplying equipment, services and personnel. This opens up thousands of jobs for trained men and women in television and its associated field.

Television Advertising and Production Handbook is written and compiled to assist those interested in any phase of planning, setting up and operating a television station. The authors, Irving Settle and Norman Glenn, together with their associates, are all associated with nationally known firms engaged in operating or servicing the television industry.

All fields are covered in the handbook, from the methods of computing the cost of installation and operation of all types of stations through research, national and local selling, mail order programs, staging, producing, casting, publicity and censorship to the methods of obtaining personnel.

A sample script from one of the Armstrong Circle Theatre dramatic presentations together with the casting, set production, camera direction and cuing is included.

Two chapters, "Producing TV Film Commercials" by Rex Cox of Sarra Inc. and "Film Package Syndication for TV" by Everett Crosby of Bing Crosby Enterprises will appeal to the motion-picture producer.

This reviewer feels this book will be of interest to anyone contemplating a career in television but will have its greatest value to prospective owners, managers, agency executives, promotional managers and producers. The handbook would make an excellent text for college or extension courses in these fields.—*William K. Aughenbaugh*, 4014 St. Johns Ter., Cincinnati, Ohio.

1953–54 Motion Picture and Television Almanac

Published (1953) by Quigley Publications, 1270 Sixth Ave., New York 20, N.Y. i–l + 1056 pp. (including advt.), thumb indexed. 6 × 9 in. $5.00.

This is the twenty-fifth annual edition of this widely used reference work. Information on the television industry, which was incorporated in the volume for the first time last year, has this year been greatly expanded and revised. It appears interspersed throughout the book, wherever relevant, as well as in a separate section.

Following the Who's Who in Motion Pictures and Television section, a useful reference file of personalities in the industry, the Almanac comprises sections on:

Corporations — Detailed information on corporate make-up and officer personnel of the companies in the motion-picture industry.

Drive-Ins — A complete listing of the drive-in theaters of the United States and Canada, with pertinent information on each installation.

Television — Data on the industry, with corporation listings; a complete list of all the television stations authorized in the United States; FCC channel allocations, nationally; the leading advertising agencies; the Television Code; a listing of program material and its source; a list of station representatives, and other information.

Pictures — A detailed listing of all feature releases from 1944 to 1953; a company-by-company breakdown of pictures of the current season; foreign films in the United States; British films in the United States, and the origin of foreign films in the United States.

Award and Poll Winners — A listing of Academy Award winners through the years; the history of the "Oscar"; the various Quigley Publications Awards; awards of the SMPTE, and other film and television awards.

Services — A section which includes listings of the motion-picture exchanges in all the key cities of the country and Canada; distributors of trailers; film carriers; shorts, cartoon and newsreel producers; film laboratories; color processes; film storage vaults; raw stock and film libraries; literary and talent agencies; publicity representatives; government film bureaus.

Equipment — A listing of manufacturers and services; equipment listed by categories; supply dealers in the United States and Canada.

Motion-Picture Organizations — A detailed listing of film organizations, producer-distributor and exhibitor; guilds and unions; Variety Clubs, film clubs and miscellaneous groups.

Codes — A full text of the Motion Picture Production Code; Motion Picture Advertising Code; Television Code; listing of censorship boards in the United States; public previewing groups; motion-picture councils.

World Market — Detailed information on the film industry in various countries of the world, with market analyses.

Great Britain — A complete set of data on the industry in Great Britain, with listings of companies, trade organizations, government film departments, studios and laboratories, theater circuits and television units.

Press — Listings of motion-picture and television trade publications; film writers of the newspapers; television writers of the newspapers; fan magazines; national magazine writers; foreign press film correspondents.

Nontheatrical — A listing of producers of nontheatrical motion pictures for advertising, television, educational purposes and libraries.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 Membership Directory.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Allaire, Robert J., Supervisor, 16mm Printing, U.S. Army Signal Corps. **Mail:** 142-42—56 Rd., Flushing, N.Y. (M)

Babits, Victor A., Professor, Electrical Engineering, Rensselaer Polytechnic Institute. **Mail:** 64—9th St., Troy, N.Y. (M)

Baldwin, Millard W., Jr., Television Research Engineer, Bell Telephone Laboratories, Inc., Murray Hill, N.J. (M)

Barnett, Sterling, Production Manager, Photographic Analysis, Inc., KTTV Studios. **Mail:** 9006 Aqueduct Ave., Sepulveda, Calif. (M)

Birr, R. E., Illumination Engineer, Lamp Division, General Electric Co., Application Engineering, Nela Park, Cleveland 12, Ohio. (A)

Brackett, Harold E., Cinematographer. **Mail:** 280 West End Ave., New York 23, N.Y. (A)

Bransby, John, Motion-Picture Producer, John Bransby Productions. **Mail:** Dudley Rd., Wilton, Conn. (M)

Bredshnyder, Vitold, Special Effects Performer, Cameraman, Anderson Elevator Co. **Mail:** 202 W. Fifth St., Perrysburg, Ohio. (M)

Brix, John, Motion-Picture Film Editor, Sarra, Inc. **Mail:** 5449 West Henderson St., Chicago, Ill. (A)

Carlson, Arvid W., Cameraman and Editor, Douglas Productions. **Mail:** 213 West Fremont St., Arlington Heights, Ill. (A)

Chase, Richard Alan, Film Editor, WNHC Elm City Broadcasting Co. **Mail:** 70 Howe St., c/o Clarkson, Apt. 209, New Haven, Conn. (A)

Clark, Alex L., President, Alex L. Clark Limited and Magnecord Canada Limited, 2914 Bloor St., West Toronto 18, Ontario, Canada. (A)

Cogan, Jack A., Product Engineer, Eastman Kodak Co. **Mail:** 113 Nantucket Rd., Rochester 13, N.Y. (M)

Collier, William W., Chief Aviation Photographer's Mate, U.S. Navy. **Mail:** 422 West Jackson Ave., Warrinton, Fla. (A)

Cooney, Stuart M., Jr., Television Staff Engineer, Springfield Television Co. **Mail:** 40 High St., Apt. 44, Springfield 5, Mass. (A)

Daniels, William H., Director of Photography, Universal-International Pictures. **Mail:** 10307 Lorenzo Dr., Los Angeles 64, Calif. (M)

Dreyer, John F., President, Polacoat, Inc., and Depth Viewers, Inc., 9750 Conklin Rd., Blue Ash, Ohio. (M)

Edgerton, Richard O., Section Supervisor, Professional 35mm Color Film, Eastman Kodak Co. **Mail:** 104 Alameda St., Rochester 13, N.Y. (A)

Embacher, Hans R., Chief Mechanical Engineer, Optomechanisms, Inc., 216 East Second St., Mineola, Long Island, N.Y. (M)

Fason, Jack, Chief, Medical Illustration Laboratory, Veterans Administration Hospital. **Mail:** P.O. Box 8785, Denver, Colo. (M)

Felton, Elmer, Coordinator, Teacher, Phoenix Union High Schools and College District. **Mail:** 1123 West Parkview Dr., Phoenix, Ariz. (M)

Ferguson, Frank E., Film Production Specialist, Audio-Visual Center, Syracuse University, Syracuse, N.Y. (A)

Fink, Donald G., Director of Research, Philco Corp. **Mail:** 845 Dale Rd., Meadowbrook, Pa. (M)

Fleck, Lucile H., President, Vacuumate Corp., 446 W. 43 St., New York, N.Y. (A)

Gardner, Loris M., Photographic Supervisor, Los Alamos Scientific Laboratory, Box 1663, Los Alamos, N.M. (M)

George, Robert Leland, Design Engineer, Berndt-Bach, Inc. **Mail:** 5246 Bindewald Rd., Torrance, Calif. (M)

Gevatoff, Sam, Motion-Picture Timer, Signal Corps Photo Center. **Mail:** 1484 Watson Ave., Bronx, N.Y. (M)

Gobrecht, Robert L., Cameraman, Director, Audio-Visual Center, Syracuse University. **Mail:** Technical Corporation ADM, APO 205, c/o Postmaster, New York, N.Y. (A)

Goldwasser, Samuel R., Chemist, Color Laboratory, Signal Corps Pictorial Center. **Mail:** 2285 Ocean Ave., Brooklyn 29, N.Y. (A)

Gregor, William, Camera Technician, Radio Optical Research Co., 617 North La Peer Dr., West Hollywood, Calif. (M)

Grodewald, Herbert H., Partner, Technical Film Studio. **Mail:** 147-17 Cherry Ave., Flushing, N.Y. (M)

Groshan, Robert M., Professional Cinemaphotographer. **Mail:** 2422 Tuscarawas St., West, Canton, Ohio. (M)

Hackett, R., Supervisor, Audio-Visual Education, York Township Board of Education. **Mail:** 57 Eagle Rd., Toronto, Ontario, Canada. (A)

Hall, Don, Jr., Production Assistant, Mercury International Pictures, 6611 Santa Monica Blvd., Hollywood 38, Calif. (M)

Hamid, Mohammed, Engineer, Photographer, Embassy of Pakistan, 2201 R St., N.W., Washington, D.C. (A)

Hayes, John Edmund, Professional Engineer, Canadian Broadcasting Corp., P.O. Box 6000, Montreal, Quebec, Canada. (M)

Hecht, William, Product Engineer, International Projector Corp. **Mail:** 29 South Munn Ave., East Orange, N.J. (M)

Heller, Herman S., Owner, Manager, Herman S. Heller and Associates, 8414 West Third St., Los Angeles 48, Calif. (M)

Hochman, Alan, Photographer's Assistant, Walter Engel Studios. **Mail:** 3240 Henry Hudson Parkway, Riverdale, N.Y. (A)

Hogan, John V. L., President, Consulting Engineer, Hogan Laboratories, Inc. **Mail:** 239 Greenway South, Forest Hills 75, Long Island, N.Y. (M)

Hsu, James, Producer, President, Crown Cinema Corp. **Mail:** 33 Piccadilly Rd., Great Neck, N.Y. (A)

Ianuzzi, Anthony Pete, Mechanical Engineer, Myerberg Productions, Inc., 216 E. Second St., New York, N.Y. (A)

Iserman, Milton L., Printer, General Film Laboratories Corp. **Mail:** 6916 Bertrand Ave., Reseda, Calif. (A)

Iwabuchi, Kiichi, Chief Engineer, Toho Film Co. **Mail:** 813 Unanecho Setagayaku, Tokyo, Japan. (M)

Jabroff, Charles, Photographic Engineer, Signal Corps. **Mail:** 258 Bath Ave., Long Branch, N.J. (A)

Johnson, Herbert H., Jr., Process Chemist, Photo Products Dept., E. I. du Pont de Nemours & Co. **Mail:** 82 Kemp Ave., Fair Haven, N.J. (M)

Johnstone, James R., Manager, Carbon Product Sales, National Carbon Co., 30 E. 42 St., New York 17, N.Y. (M)

Jones, Daniel J., Development Engineer, Eastman Kodak Co. **Mail:** 512 Daytona Ave., Webster, N.Y. (A)

Juett, Francis Edward, Processing Manager, George Humphries & Co., Ltd. **Mail:** 3 Oakwood Ave., Boreham Wood, Herts, England. (A)

Kellman, Louis W., Motion-Picture Producer. **Mail:** 1729–31 Sansom St., Philadelphia, Pa. (M)

Kennedy, Richard F., Soundman, Business Manager, Audio-Visual Center, Syracuse University. **Mail:** c/o T.C.I., U.S. Embassy, Tehran, Iran. (A)

Knoblock, George C., Supervisor, Film Assembly and Inspection, Wilding Picture Productions, Inc. **Mail:** 1529 West Roscoe St., Chicago 13, Ill. (A)

Leichman, Alfred C., Theatre Ticket Clerk, Mutual Theatre Ticket Co. **Mail:** 129 W. 48 St., c/o Bristol, New York 36, N.Y. (A)

Levine, John H., Motion-Picture Projectionist, Sound Technician, Poli—New England Theatres, Inc. **Mail:** 9 Kelley Square, Worcester 4, Mass. (M)

Lundy, Curtis S., Service Inspector, Altec Service Corp. **Mail:** P.O. Box 1386, Lansing 4, Mich. (A)

Mahnke, Carl F., Jr., Production Manager, Carl F. Mahnke Productions, 215 East Third St., Des Moines 9, Iowa. (A)

Malkames, Karl, Newsreel Cameraman, Warner Brothers Pathe News Inc. **Mail:** 22 Benedict Rd., Fulton Park, White Plains, N.Y. (M)

Manning, David D., Film Director, WHAM-TV; President, General Manager, Tele-Visuals, Inc. **Mail:** 42 Del Rio Dr., Rochester 18, N.Y. (M)

Marshall, Eldon L., Cinematographer, Hughes Sound Films. **Mail:** 2111 Poplar, Denver 7, Colo. (M)

Marsten, Francis R., Sensitometrist, Signal Corps Pictorial Center. **Mail:** 229 South Broadway, Yonkers 5, N.Y. (A)

Matzko, Gustave, Supervisor, Motion-Picture Laboratory Maintenance, U.S. Army Signal Corps. **Mail:** 126 Bennett Ave., Yonkers, N.Y. (A)

Miller, C. David, Assistant Supervisor in Engineering Research, Battelle Memorial Institute. **Mail:** 1268 West Second Ave., Columbus 12, Ohio. (M)

Moone, Levi E., Motion-Picture Cameraman and Laboratory Supervisor, U.S. Government. **Mail:** 5557 Livingston Rd., Washington, D.C. (M)

Muehlstein, Daniel F., Photographic Engineer, Eastman Kodak Co., 1712 South Prairie Ave., Chicago 16, Ill. (M)

Nallan, William J., Jr., Sound Engineer, Fox Movietone. **Mail:** 2 Tree La., Wantagh, Long Island, N.Y. (M)

Nelson, Edward J., Engineer, Ballantyne Co., 1712 Jackson, Omaha, Nebr. (M)

Neumer, A. E., Optical Engineer, Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N.Y. (M)

Noble, James J., Engineer, Altec Lansing Corp., 9356 Santa Monica Blvd., Beverly Hills, Calif. (M)

Peed, Allie C., Jr., Technical Editor, Eastman Kodak Co., Sales Service Division, 343 State St., Rochester, N.Y. (M)

Peirano, Augusto Roca, Motion-Picture Laboratory, Instituto Cinematografico Boliviano, Indaburo 212, Postal Box 2368, La Paz, Bolivia, S.A. (M)

Perry, Charles A., Motion-Picture Director Pilot Productions, Inc. **Mail:** 1804 McCormick Blvd., Evanston, Ill. (M)

Peters, Hugh Griffith, Producer, President, Peters and Co., 227 West Boscawen St., Winchester, Va. (M)

Pomeroy, Robert R., General Engineer, U.S. Navy Special Devices Center. **Mail:** 51 Mackey Ave., Port Washington, N.Y. (A)

Price, R. Lee, Senior Electronic Engineer, Magnecord, Inc. **Mail:** 756 South Highland Ave., Barrington, Ill. (M)

Randon, Lee, Film Director, Producer, Henri, Hurst & McDonald, Inc. **Mail:** 406 Dewey Ave., Evanston, Ill. (M)

Ray, George A., Jr., Mechanical and Electrical Engineer, Motiograph, Inc., 4431 W. Lake St., Chicago 24, Ill. (M)

Riefberg, Morton I., Chemist, U.S. Army Signal Corps. **Mail:** 205 Sea Breeze Ave., Brooklyn 24, N.Y. (A)

Roat, Edward S., Chemist, Eastman Kodak Co. **Mail:** 83 Gorsline St., Rochester 13, N.Y. (A)

Rodriguez S., Abelardo, Distributor, FOTO Mexico SA DE CV, Avenue CuauhTemoc 130, Mexico, D.F., Mexico (A)

Runde, Fred J., Jr., Motion-Picture Cameraman, E. I. du Pont de Nemours & Co. **Mail:** 2241 Cumming Rd., Augusta, Ga. (A)

Salzberg, Emmett R., Motion-Picture Film Processing, Precision Film Laboratories, Inc. **Mail:** 514 West 110 St., New York 25, N.Y. (A)

Schartel, Egon, Film Technician, Quality Control, Consolidated Film Industries. **Mail:** 7 Hazlitt Ave., Fort Lee, N.J. (M)

Schlanger, Sam, Engineer, Camera Equipment Co. **Mail:** 44 Forest Rd., Valley Stream, Long Island, N.Y. (A)

Schubert, Alvin E., General Superintendent, Development and Engineering, Eastman Kodak Co., 343 State St., Rochester, N.Y. (M)

Seda, Anton C., Engineer, De Vry Corp. **Mail:** 129 North Charles Ave., Villa Park, Ill. (A)

DECEASED

Russey, Elwood M., Director of Photography, Byron, Inc. **Mail:** Box 45, RFD #1, Vienna, Va. (M)

Serrurier, Mark, Owner, Moviola Manufacturing Co., 1451 Gordon St., Hollywood 28, Calif. (M)

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April 1952 *Journal*.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, and there is no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Experienced motion-picture production man desires connection with film company as producer-director or production manager. During past 12 yrs. experience includes directing, photographing, editing, recording and processing half-million feet finished film, including educational films, industrials, TV spots, package shows for TV and experimental films. University graduate, married, twenty-nine years old; good references. Locate anywhere continental U.S. Write Victor Duncan, 8715 Rexford Drive, Dallas 9, Tex.

Film Production/Use: Experienced in writing, directing, editing, photography; currently in charge of public relations, sales and training film production for industrial organization. Solid film and TV background, capable administrator, creative ability, degree. References and résumé upon request. Write FPF, Room 704, 342 Madison Ave., New York 17, N.Y.

Engineer, B.M.E.: Creative designs, product improvement. Photographic and electronic-mechanical fields. Cameras (film, image-orthicon and iconoscope TV cameras), color film processing, production tooling, radar. Simple constructions, pleasing appearance. Special product or production blueprints. Write J. Rafalow, Selden, N.Y.

Meetings

Theatre Equipment and Supply Manufacturers' Association Convention (in conjunction with Theatre Equipment Dealers' Association and Theatre Owners of America), Oct. 31–Nov. 4, Conrad Hilton Hotel, Chicago, Ill.

Theatre Owners of America, Annual Convention and Trade Show, Nov. 1–5, Chicago, Ill.

National Electrical Manufacturers Association, Nov. 9–12, Haddon Hall Hotel, Atlantic City, N.J.

Society of Motion Picture and Television Engineers, Central Section Meeting, Nov. 12 (tentative), Chicago Ill.

The American Society of Mechanical Engineers, Annual Meeting, Nov. 29–Dec. 4, Statler Hotel, N.Y.

Society of Motion Picture and Television Engineers, Central Section Meeting, Dec. 10 (tentative), Chicago, Ill.

American Institute of Chemical Engineers, Annual Meeting, Dec. 13–16, St. Louis, Mo.

American Institute of Electrical Engineers, Winter General Meeting, Jan. 18–22, 1954, New York

National Electrical Manufacturers Assn., Mar. 8–11, 1954, Edgewater Beach Hotel, Chicago, Ill.

Radio Engineering Show and I.R.E. National Convention, Mar. 22–25, 1954, Hotel Waldorf Astoria, New York

Optical Society of America, Mar. 25–27, 1954, New York

75th Semiannual Convention of the SMPTE, May 3–7, 1954, Hotel Statler, Washington

American Institute of Electrical Engineers, Summer General Meeting, June 21–25, 1954, Los Angeles, Calif.

Acoustical Society of America, June 22–26, 1954, Hotel Statler, New York

76th Semiannual Convention of the SMPTE, Oct. 18–22, 1954 (next year), Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955, Drake Hotel, Chicago

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955, Lake Placid Club, Essex County, N.Y.

Basic Principles of Stereophonic Sound

By WILLIAM B. SNOW

Stereophonic sound has become of vital importance to industry. The subject has been studied for many years, but the published material is scattered. This paper summarizes the fundamental theory underlying stereophonic sound so far as it has been published, and gives examples of how the theory is employed in representative practical situations. Fundamental differences between ordinary binaural listening and stereophony are pointed out, as well as similarities. It is shown that much qualitative but little quantitative information has been reported. Factors which aid some stereophonic effects are shown to be detrimental to others, and methods of minimizing the undesirable conditions are suggested. Applications to recording are discussed.

In 1941 K. de Boer wrote: "When the time comes to make use of stereophonic reproduction in the cinema, in broadcasting, etc., and the opinion becomes more and more general that the improvement in quality so obtained is worth the trouble, it will become necessary in the first place to find a process of making stereophonic records on a large scale."[6] Although even at that time stereophonic reproduction was far from new,[19–21] de Boer's enthusiasm for "making an orchestra plastically audible"[5] was shared by only a few. Now the time he forecast has finally come. Stereophonic sound has suddenly become of vital concern to the motion-picture and sound-recording industries, with multiple-channel recording the order of the day. This great upsurge of interest encouraged the preparation of this review of basic principles, and bibliography, as a guide for the large number of engineers who must quickly put this new technique into everyday use.

Stereophonic reproduction brings a truly remarkable increase in the realism of the sound and in the pleasure of listening to it. In one attempt to measure this quantitatively, reported by Fletcher,[2] the observers listened alternately to single-channel and stereophonic reproduction. In the stereophonic channels low-pass filters were inserted, while the single channel was maintained flat

Presented on October 5, 1953, at the Society's Convention at New York by William B. Snow, Consultant in Acoustics, 1011 Georgina Ave., Santa Monica, Calif.
(This paper was received September 2, 1953.)

to 15 kc. Half of the observers still preferred stereophonic reproduction when the low-pass cutoff was reduced to about 5 kc. However, this paper is concerned primarily with the mechanism of stereophonic sound rather than its advantages, which are now so well recognized. It is not the purpose here to repeat detailed discussions that can readily be found in the references. Such data are summarized, and additional interpretation is provided. The serious reader is strongly urged to study the references carefully; a good grounding in this complicated subject can be obtained only in this way.

DEFINITIONS

As in most new developments, differences in nomenclature have arisen which tend to obscure precise descriptions of systems. The words "binaural" and "stereophonic" are those most frequently used, but not with uniform meanings. This is not a new phenomenon. Alexander Graham Bell, writing in 1880,[1] referred to the "stereophonic phenomena of binaural audition," in describing experiments on the directional sense in hearing conducted with his newly invented telephone. The following definitions apply to the discussions of this paper and are limited to electro-acoustic sound-reproducing systems:

Binaural — A system employing two microphones, preferably in an artificial head, two independent amplifying channels, and two independent headphones for each observer. This duplicates normal listening.

Stereophonic — A system employing two or more microphones spaced in front of a pickup area, connected by independent amplifying channels to two or more loudspeakers spaced in front of a listening area. This creates the illusion of sounds having direction and depth in the area between the loudspeakers.

It is very important to distinguish between these systems. A binaural transmission system actually *duplicates* in the listener's ears the sounds he would hear at the pickup point, and except that he cannot turn the dummy head, gives full normal directional sense in all directions. A stereophonic system produces an abnormal sound pattern at the listener's ears which his hearing sense *interprets* as indicating direction in the limited space between the loudspeakers. It has been aptly said that the binaural system transports the listener to the original scene, whereas the stereophonic system transports the sound source to the listener's room.

ELECTRO-ACOUSTIC SOUND-REPRODUCING SYSTEMS

Outstanding differences and similarities of the various types of electro-acoustic reproducing systems are summarized in the chart of Fig. 1. The "System" names in column 1 conform to a uniform pattern and will be found in the literature, except "Monophonic" which is used for convenience as the opposite of stereophonic. "Equivalent Normal Experience" refers to the everyday hearing experience that most closely parallels listening over the systems in question. The next four columns are obvious. The column "Direct Sound Reproduction of Single Source Pulse" is probably the most important, since it gives the basic differences between the sound produced by the various systems. If a single sound pulse is produced by the source, this column gives the characteristics of the resulting *direct* sound pulses at the observer's ears. The direct sound is the initial sound transmitted directly from source to observer by the shortest path, and arriving before any reflected sound arrives. It has been found that the direct sound carries the information, making angular perception possible, and it will be referred to frequently in what follows. Reverberant sound arrives from many angles and confuses the directional perception if too great in intensity. The "Remarks" column gives qualifying comments concerning the sound reproduction of each system. The reasoning behind these remarks is given in the body of the paper.

BINAURAL REPRODUCTION

Binaural reproduction as used herein means ordinary two-ear listening since the reproducing system transmits a faithful copy of the original sound to the listener's ears.

Angular Localization

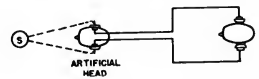
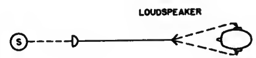
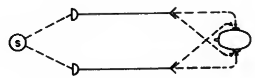
The properties of hearing which give the directional sense in binaural listening have been studied extensively.[11–18] For pure tones, angular localization is produced partially by phase differences at the two ears caused by the difference in distance from source to the ears as the source angle changes. The phase effect becomes ambiguous somewhat above 1000 cycles because at short wavelengths more than one angle results in the same phase difference. However, in the higher-frequency region intensity differences produced by the diffraction or sound-shadow effects of the head and external ears become great enough to give angular localization.

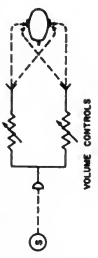
The great majority of sounds are not pure tones, but complex. For complex sounds the equivalent effects are arrival time and quality difference. A complex wave pulse has an initial wavefront which arrives at the near ear a short time before it arrives at the far ear. It is this small time difference which is used by the hearing sense to determine small angular variations, particularly for sounds near the median plane (straight ahead). It is characteristic to turn toward a source to locate it with maximum precision, and for impulsive sounds such as speech or clicks, differences as small as 1° to 2° can be perceived. These angles correspond to arrival-time differences of about 10 to 20 μsec, and the maximum possible difference, for a source in line with the two ears, is only about 700 μsec. The loudness differences at such small angles are negligible and it must be assumed that the arrival-time differences give the localization clues. On the other hand, it is not possible for the mechanism of a *single* ear to distinguish such short time intervals[17]; this "decoding" of the arrival time differences must be accomplished by the brain.

The arrival-time effect is aided by the quality differences at the ears caused by sound diffraction.[22] Quality difference is another way of saying that a change in waveshape is produced. The intensity differences due to diffraction are functions of frequency and cause a complex sound to have a different frequency-intensity composition or quality at each ear. It is undoubtedly this effect which removes ambiguities in direction which would result from arrival time alone, because the diffraction effects are so complicated that a given quality difference can correspond only to one direction. Quality differences also change most rapidly near the median direction; consequently, angular localization is much less precise at the side than in front or back.

Changes in both arrival time and quality are relatively small as a source is elevated in front of an observer. Therefore the ability to distinguish angle in the vertical direction is relatively poor.

Fig. 1. Electro-acoustic sound reproducing systems.

Type of system	Equivalent normal experience	Pickup	Number of channels	Reproducer	Symbolic schematic	Direct sound reproduction of single source pulse	Remarks
Monaural	One ear plugged	1 Microphone	1	1 Headphone		1 Pulse to 1 ear	Only partial equivalence, as directional effects are not duplicated
Diotic	Sound source in median plane only	1 Microphone	1	2 Headphones		1 Pulse to each ear 0 time difference No quality difference	Only partial, as directional effects of elevation not duplicated. No directional effect of room reverberation Qualitatively much superior to monaural
Binaural	Normal listening, head stationary	2 Microphones in artificial head	2	2 Headphones		1 Pulse to each ear 0 to 0.6 msec time difference Normal quality differences	Directional and quality effects of normal listening in *pickup room duplicated* throughout *360° sphere* *No* listening room effects Observer cannot turn to face virtual source
"Monophonic" ordinary loudspeaker	Sound coming through a hole in a wall	1 Microphone	1	1 Loudspeaker		1 Pulse to each ear 0 time differences No quality differences	Both ears used—binaural listening to a single fixed sound source position Composite of pickup and listening room acoustics Listening room reverberation has directivity Represents widely spaced "effects" loudspeakers
Stereophonic	None	2 or more microphones	2 or more	2 or more loudspeakers		2 or more pulses to *each* ear 0 to 30+ msec time differences Complex quality differences	Depends on fusion of multiple pulses by ears Directional and quality effects of normal listening *simulated* for a *limited angular area* appearing as part of *listening room* 360° simulation would require a large number of channels Composite of pickup and listening room acoustics Reverberation has partial directivity in pickup room, full directivity in listening room Observer can turn to face virtual source Time differences from both source and observer positions

Pseudo or bridged stereophonic	None	1 Microphone	2 or more	2 or more loudspeakers		2 or more pulses to *each* ear 0 to 20+ msec time differences Small quality differences	Single source only Many properties identical with true stereophonic system Time differences *only* from observer position, and detrimental Identical signal-reverberation pattern from each loudspeaker Identical quality from each loudspeaker Many other bridged combinations possible

The statement is made in Fig. 1 that the observer cannot turn to face the source. While systems have been constructed with servo connections between observer and dummy,[7] thereby improving localization, this is not practicable for a system used with multiple observers, or with a recording link.

Depth Localization

Perceiving the position of a sound source in space involves the determination of distance as well as angle. The ear has no mechanism corresponding to that of the eye for converging on the source, and must depend on less definite clues. In the absence of reverberation, the only information given is intensity and quality. From past experience the ear can form an approximate idea of distance from its interpretation of the *absolute* loudness of a sound, and from its judgment of quality differences produced by atmospheric absorption. These comparisons are made with a mental image of what the sound should be. In the presence of reverberation,[23] the ear can judge distance based on the ratio of direct to reverberant sound. Since neither of these methods is precise, judgment of distance is much less accurate than perception of angle. Probably everyone has had the experience of badly misjudging the distance of a sound heard for the first time, whereas no difficulty was experienced in determining its direction.

Fundamental Difference from Stereophonic Sound

This discussion of the determining physical factors underlying ordinary binaural hearing has been given at some length to lay a foundation for the discussion of those underlying stereophonic reproduction. There are basic differences which have been almost universally overlooked. When this confusion is cleared up, stereophonic reproduction can be used with much greater ease and satisfaction.

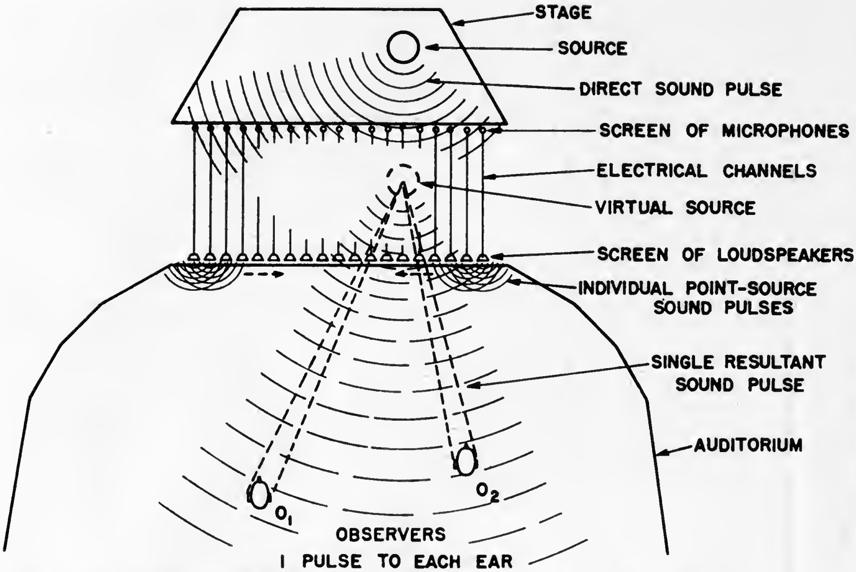


Fig. 2. Ideal stereophonic system. A very large number of very small microphones and loudspeakers would give a perfect reproduction of the original sound.

STEREOPHONIC REPRODUCTION

Fundamental Process

Publications. Good summaries of stereophonic sound are given by Frayne and Wolfe[24] and Knudsen and Harris.[25] Only a few reports on the fundamental principles of stereophonic reproduction have appeared in the literature[4,8,9,17,27,39] and these do not discuss identical operating systems. The Bell System tests and those at Twentieth Century-Fox Studios were made with widely spaced microphones, whereas scientists of the Philips Company employed closely spaced microphones, usually in an artificial head. It is unfortunate that additional fundamental tests made at Bell Telephone Laboratories were never reported in technical journals because of the press of other work and the advent of the War. In spite of this, we believe it is possible to understand the principles qualitatively, if not fully on a quantitative basis, and that the results so far published are for the most part consistent.

Screen Analogy. It has become customary to describe stereophonic reproduction as follows: A screen consisting of an extremely large number of extremely small microphones is hung in front of the sound source. Each microphone is connected to a corresponding extremely small loudspeaker in a screen of loudspeakers hung before the audience. Then the sound projected at the audience will be a faithful copy of the original sound and an observer will hear the sound in true auditory perspective. It is then stated that such an impractically large number of channels is not needed and that good auditory perspective can be achieved with only two or three channels. These are true statements, and the natural inference from their juxtaposition is that far less than faithful "space" reproduction of sound will give localization by ordinary binaural mechanisms. When we proposed this theory early in

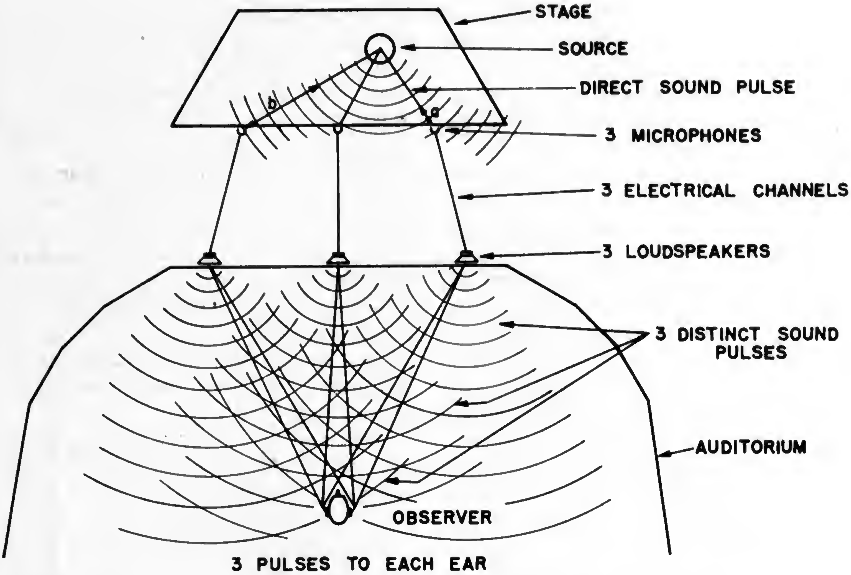


Fig. 3. Actual 3-channel stereophonic system. A practical stereophonic system gives a multiple reproduction of the original sound which the observer interprets as coming from a single source.

our studies of stereophonic phenomena, we realized that there were fundamental differences which were not fully understood, and pointed out the multiple source effect in connection with our loudness calculations.[26,27] Apparently this has not been sufficiently emphasized. The experience of the intervening twenty years has convinced this writer that this natural inference is mistaken, and has caused the confusion postulated in the previous section.

The myriad loudspeakers of the screen, acting as point sources of sound identical with the sounds heard by the microphones, would project a true copy of the original sound into the listening area. The observer *would* then employ ordinary binaural listening, and his ears would be stimulated by sounds *identical* to those he would have heard coming from the original sound source. As shown in Fig. 1, this means one direct-sound pulse to each ear for a single pulse from the source. The phenomena are illustrated schematically in Fig. 2.

Operating Conditions — Illusion Created. Figure 3 illustrates the conditions for a typical setup where only three channels are used. This arrangement does indeed give good auditory perspective, but what has not been generally appreciated is that conditions are now so different from the impractical "infinite screen" setup that a different hearing mechanism is used by the brain. Each individual loudspeaker sends a pulse to the observer. He therefore receives *three* faithful copies of the sound at *each* ear in rapid succession. The time differences between these pulses are too short to allow the ear to distinguish them as separate; consequently the hearing mechanism fuses them[17] into an *illusion* of a single sound pulse coming from a virtual sound source located somewhere in the space between the outer loudspeakers. The time differences are short, but still long compared to the maximum of 700 μsec to which the ears are accustomed in normal listening. Thus this type of listening falls outside of normal experience, but fortunately the brain is able to form a single concise impression from what might be expected to be a confusing set of signals sent by the ears.

The closest parallel is reverberation. But while there are distinct similarities, the three direct-sound pulses arrive ahead of any reflections other than the floor reflections which do not have individual directivity. In addition, they are separate and distinct, of high fidelity, and in a compact directive pattern. The reverberation follows as a "smear" of echoes of random directivity, and does not create a virtual source illusion.

The problem, then, in stereophonic reproduction is to produce multiple sound images at the ears of the observer which will fuse in such a way as to give the desired *illusion* of sound origin.

Angular Perception

Intensity Differences. What are the characteristics of the direct-sound pulses which cause them to give the observer the sensation of angular localization of the virtual source? The most obvious difference is intensity of sound projected by the several loudspeakers. These differences are caused by the varying distances of the source from the various microphones. When the source moves close to a microphone the output of the corresponding loudspeaker is greater than that of the other loudspeakers, and localization tends in its direction. The virtual source therefore moves in the same direction as the real source, and with proper system design can be made to have essentially proportional movement. In the original paper[27] Dr. Steinberg and this writer discussed this in detail and proposed a theory for the effect of these intensity differences, based upon the total loudness that would be produced in each ear by the total direct sound from all loudspeakers, taking into account the directivity of hearing caused by the shape of the head. While the agreement between the theory and experimental results was by no means perfect and the differences were pointed out, the theory did appear to account for the main effect. This theory has been questioned by other experimenters, principally, it is believed, because of the common confusion between the mechanisms of ordinary binaural hearing and stereophonic hearing which the discussion above should have now dispelled.

While a true understanding of the process is highly desirable, for the purposes of this paper it is not necessary to be certain of the precise physiological and psychological mechanisms involved. It is well established that intensity differences in the channels are an extremely important contributor to angular perception. With positions of source and observer fixed so that all other factors are constant, variation of the gain controls in the channels can shift the virtual source to any angular position in the reproducing area. This is true for any combination of source and observer positions. In practice this is important because gain is easily controlled, to correct faults in pickup, or to enhance angular movement. The bridged-microphone system of Fig. 1 operates on this basis, since the only differences that can be given the loudspeaker outputs must be obtained from electrical controls in the channels. As this is written, many pictures are being made "stereophonic" by the use of volume controls in bridged channels from sound tracks originally recorded for single channel or "monophonic" reproduction. The pseudo-stereophonic system has its place; but it is not a satisfactory substitute for a real stereophonic pickup. It does not have the benefit of the other aids to angular or depth perception described below; and in particular it can be used on only a single source at one time, so that an individual source and "pan-pot" must be supplied for each sound.

Quality Differences. If the microphones have varying directivity with frequency, there are quality differences as well as intensity differences in the channels as the source moves. Angular localization is definitely affected by this. It has been found that the higher frequencies, where the head has relatively high directivity, contribute most to stereophonic localization. Localization tends toward the loudspeaker giving greatest high-frequency output, if the overall loudness is the same.

The very low frequencies contribute essentially nothing to stereophonic localization. For example, poor localization results if 1000-cycle low-pass filters are inserted, and no difference in localization is produced by eliminating frequencies below 300 cycles. It has been found[4,10,40] that much of the stereophonic effect is preserved if low frequencies are reproduced from only one low-frequency unit and side channels reproducing only frequencies above 300 cycles are employed. This is of great practical value for economical stereophonic reproduction such as home music systems. For the flexibility and high fidelity demanded by motion-picture and auditorium reproduction its use appears questionable until a great deal more study of it has been reported. The Philips tests[10] employed microphones a small distance apart; with widely spaced microphones characterizing the practice in this country serious pickup difficulties can be foreseen, as well as "crossover" complications in the loudspeaker systems. For "special effects loudspeakers," however, the low frequencies do not appear necessary if the main object is to obtain localization.

Arrival-Time Differences. Another phenomenon affecting angular localization is the change in arrival time of the direct-sound pulses from the several loudspeakers as the source moves upon the stage. These differences were mentioned above, and were shown to be considerably greater than those ordinarily encountered in simple binaural hearing. For example, in Fig. 3 the right and left channels reproduce sound pulses from the source later than the center channel by time intervals corresponding to distances *a* and *b*, respectively. The observer does not recognize the three pulses as distinct. However, it has been shown[17,41] that localization tends towards the loudspeaker which reproduces the earliest pulse. These effects have been called "Fusion" and the "Precedence Effect" by the authors of Ref. 17, who give a clear and detailed discussion of their relation to stereophonic reproduction. Qualitatively their discussion applies to stereophonic reproduction in general, but the precise data on precedence is limited to time differences of 2 msec or less, whereas common stereophonic conditions produce differences much greater than this. The following qualitative statements are deduced from this writer's own experience:

(a) The effect of arrival time is to make localization tend toward the loudspeaker from which the pulse arrives first.

(b) This effect is strong for small differences, say up to 3 or 4 msec, and tends to become weaker for greater time differences.

(c) The effect is relatively independent of where the differences are produced, whether on the pickup stage, in the listening room, or in the reproducing channels. Therefore differences in one section add to those in another, or can be made to compensate each other.

(d) These effects can be largely compensated by intensity or quality differences inserted in the channels, for any one observing position.

This effect acts to reinforce the

intensity effect for movement on the pickup stage. As a source moves toward a microphone the arrival time is advanced at the same time that intensity is increased. This is one of the important factors not duplicated by the bridged system. An interesting application is described by Grignon[39] in the triangular microphone arrangement for assuring center localization while maintaining stereophonic quality for a soloist or small source. Here the small advance of arrival time on the center microphone holds localization to the corresponding loudspeaker.

Reverberation. A fourth factor that might contribute to angular localization is ratio of direct to reverberant sound. Experience has shown, however, that it plays a very minor part in angular localization.

Dynamic Localization. Moir and Leslie[18] provide a very interesting observation on localization, as follows: "...dynamic localization of a source appears to be appreciably more accurate than is shown by the data obtained from localization tests on a stationary source. This applies to all variations of two- and three-channel systems that we have compared."

Depth Perception

Depth perception in stereophonic reproduction is controlled by essentially the same factors as in ordinary binaural listening described above, viz.: absolute intensity, quality, and ratio of direct to reverberant sound.[27] As the sound intensity decreases, the impression is produced of the sound moving away. The same illusion accompanies a relative loss of high frequencies. The most important contributor to the feeling of depth, however, is change in the ratio of direct to reverberant sound on the pickup stage. As the reverberant energy becomes more prominent, the source appears to recede on the virtual stage. In practice the microphones are closer to the sound sources than listeners would be, and changes in direct-to-reverberant sound ratio can be heightened to give more definite impressions of depth on a virtual stage than are created on a real stage. This can be seen in Fig. 1 of Ref. 27. As in ordinary listening, however, depth localization is less precise than angular localization.

Effect of Observer Position

Up to this point, for the sake of simplicity, the paper has been written as if all observing positions were equally good. Actually this is far from the case, as all experimenters have pointed out. From the standpoint of the practical use of stereophonic reproduction in the theater, this is a truly serious problem. Here the very factors which produce the stereophonic effect prove a disadvantage in some aspects, and measures must be taken to compensate them.

Source Position Shift as Observer Moves. The effects so far described characterize listening at the position of Fig. 3, or other listening positions on the center line where the distances to the side loudspeakers are equal. They also apply to other observing positions qualitatively, but as the observer moves away from the center large shifts of virtual source position may occur. The stereophonic feeling of spaciousness is preserved, and virtual sources continue to move, but they are not localized at the same place on the stage by all listeners as they would be on a real stage.

Figure 4 illustrates what is happening, for a source at center of the pickup stage, and a typical setup. Observer 1 receives identical direct sound pulses from the two side channels. Even here, however, the center-channel sound arrives slightly ahead of that from the sides, and at greater amplitude. In practice, the center channel is operated at lower gain than the side channels to correct for this.

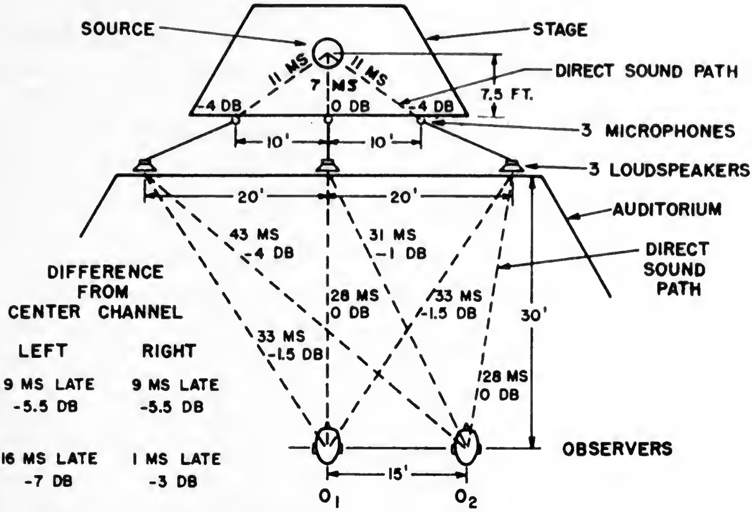


Fig. 4. Effect of changing listening location. As the observer moves away from the center-line of the auditorium the sound from the "near" loudspeaker increases in intensity and decreases in relative arrival time, making the virtual source shift in the same direction.

Observer 2 at the right receives pulses from the three loudspeakers with the relative times and intensity levels shown. It is seen that the righthand loudspeaker now contributes both a more intense signal and an earlier signal than before; and both of these effects are known to make localization tend in its direction. This is indeed the case, and as the observer moves to the right the virtual source position moves in the same direction. Note that the differences in time are several milliseconds. Qualitatively (again based upon personal experience) it is found that a considerable shift takes place for small observer deviations from the center, where relative intensity changes are small. These must be ascribed to changes in arrival time. For any given observer position these shifts can be compensated by changes in channel gains, and appear to become relatively constant at anything over a few milliseconds. Obviously the effects of intensity increase can be overcome by unbalancing the channel gains.

Methods of Reducing Shifts. The patent of Ref. 41 contains a suggested method of alleviating these troubles. The loudspeakers would be so designed as to project a delayed signal and one of reduced intensity in the forward direction compared to the side directions. This would tend to equalize conditions for the various observing positions.

Suppose that observer 2 remains at the right while the source moves to the left. The intensity increases in the left channel, but more important the arrival times become more nearly equalized, and the virtual source moves toward the left. Only the intensity change is duplicated in the bridged channel, so that there is definite advantage in the real system considering all observing positions. If the source moves to the right, the arrival time disparity is aggravated; but since there appears to be a limit to the effect of arrival time this negative effect is smaller than the positive advantage for movement to the left, and an overall gain results.

If the observer turns his head to follow movement of the virtual source, the effect is to oppose the movement, since the ear on the side of the head in the direction of movement in effect turns away from the loudspeaker of increasing intensity, and the opposite ear turns toward the loudspeaker of decreasing intensity. Since the sound tends to move "too fast" toward the microphone being approached because of the combined effects of intensity and arrival time, this is an advantageous compensating factor, considering all seats in the auditorium.

APPLICATION OF BASIC PRINCIPLES

The practical art of applying stereophonic reproduction for public use is now building up rapidly, and many papers may be expected in the future. The various references contain data on the small number of tests made previous to 1952, notably Ref. 39 in which Grignon describes tests specifically designed to determine techniques applicable to motion-picture production. The present paper is concerned primarily with the underlying principles, but it seems useful to give some illustrative examples of how they are used. These examples are primarily of situations with which the author has had personal experience.

Number of Channels

The number of channels will depend upon the size of the stage and listening rooms, and the precision in localization desired. Two channels give a large measure of the spacious effect desired for stereophonic reproduction, and will give fairly accurate localization for a small stage. Such a system on an ordinary-sized stage will give quite different localization impressions to observers in different parts of the auditorium, and is apt to suffer from the "hole-in-the-center" effect where all sounds at center stage seem to recede toward the back. Nevertheless, for a use such as rendition of music in the home, where economy is required and accurate placement of sources is not of great importance if the feeling of separation of sources is preserved, two-channel reproduction is of real importance.

That this is true is borne out by the current sponsored programs being broadcast by radio stations in various parts of the country using the FM transmitter for one channel and the AM transmitter for the other. Experience with this service in the writer's home has demonstrated the great increase in enjoyment it provides. Various methods for utilizing a single carrier for this type of broadcasting have been proposed,[18,40,42] using upper and lower sidebands separately, simultaneous AM and FM modulation, and modulating one channel on a subcarrier which is then modulated with the other channel on a regular FM transmitter. For such service the idea of supplying only one low-frequency loudspeaker appears important. It is well to recognize that a poor crosstalk ratio between channels in such a stereophonic system is not serious, because the relative intensity levels in the two channels never become greatly different. Thus systems which could not be considered for separate programs may be usable for stereophonic reproduction.

Three channels appear to be a good economic choice for ordinary stages and auditoriums. Good accuracy of localization can be achieved for favorable observing positions, with reasonable results at other seating locations. The center channel is a great aid for solo and close-up work, as well as removing the "hole-in-the-center" effect mentioned above. For unusually wide stages, additional channels have been found necessary.[43,44] At present it may be taken as a rule of thumb that additional channels should be considered when stage dimensions require channels spaced more than 25 ft on centers.

Loudspeakers

Placement. Loudspeaker placement is straightforward if considered for sound alone. The outside loudspeakers are placed at the outside edges of the space considered the reproducing stage, since sound cannot be made to travel past the outside speakers. The center, or other loudspeakers are placed at uniform spacing across the stage. It was stated that the close microphone position ordinarily used makes it possible to enhance depth effects. The source can therefore be made to appear in front of the loudspeakers, and they may be placed a few feet back of the front of the stage. In the Bell System demonstration at Carnegie Hall in 1940, the outside loudspeakers were spaced 40 ft on centers, and the front of each loudspeaker was 11 ft back of the decorative sound-transparent front curtain.[35] This curtain was illuminated in various simple color patterns during the performance, an artifice which adds enjoyment when no picture accompanies the sound.

For sound-picture reproduction, the effect of the picture is great, and the precision of localization required is smaller. If the sound tends to be in the region of the visible source, it will be localized there. Consequently here it *is* possible to create the illusion of sound outside the farthest loudspeaker.

When the stereophonic system is used for sound reinforcement serious difficulty may be experienced in placing the loudspeakers where they will not obstruct the view. Fortunately here, also, the source is visible. In addition, it was shown that localization in the vertical plane is poor. The loudspeakers can therefore be placed above or below the stage level without loss of illusion provided high fidelity of reproduction is maintained. It is also sometimes possible to use a smaller loudspeaker in the central positions, without full low-frequency response, to give proper localization. One of the most successful stereophonic reinforcement systems was tested in the Hollywood Bowl in 1936,[45] where the loudspeakers were mounted on a platform 45 ft above the stage level. The system supplied almost uniform sound level throughout the seating area, and considerable amplification even for the closest seats. Nevertheless the illusion that the sound came directly from the orchestra in the shell was excellent. To preserve a good illusion the loudspeakers should have approximately the same spacing as the channel microphones.

Characteristics. Since the illusion is caused by the receipt of multiple sound pulses, and in view of the observer-position effects discussed above, it is important that the loudspeakers give uniform angular coverage of the whole seating area. Actually, according to the disclosure of Ref. 41, greater energy should be supplied to seats at the side than to those in front of a loudspeaker, the inverse of the ordinary loudspeaker directional characteristic. Some toeing-in of the outside loudspeakers will help the average situation. In addition to these factors, de Boer[4] also recommends minimizing sound projection to areas outside the audience to reduce wall reflections, and maintaining the quality of the several channels above 300 cycles as alike as possible. Quality differences will be interpreted in the stereophonic illusion as differences in direction.

Bridged Loudspeakers. It is possible to bridge a center loudspeaker across the outside channels, which has the effect of reducing the apparent stage width.[6,27] This would be useful if it were impossible to place the side loudspeakers as close together as desired. It would be subject to the limitations of bridged systems already pointed out.

Microphones

Placement. Microphone placement may be simple or complicated, depending on the application. From what has been said, it will be evident that creating the stereophonic illusion is a compromise between favorable and unfavorable factors, and microphone placement and movement can be used to advantage in effecting this compromise. Since the illusion depends upon differences in intensity and arrival time at the microphones, and change in ratio of reverberant to direct sound, the microphones must be placed close enough to the sources to create these differences. This means that each microphone "covers" only part of the stage and will be closer than fixed microphones placed for single pickup. If pickup of action is necessary in a room where ordinary reverberation times obtain, the necessity of close pickup is apt to accentuate depth effect, and require a small stage area. Then dimensions are multiplied if a larger reproducing stage is used, and the speed of movement on the pickup stage must be slowed by an appropriate factor. Conversely, if the action demands a large stage, special microphone-handling techniques such as those described by Grignon[39] will probably be necessary. A good combination is a dead stage in which a set of the size that will accommodate the action can be constructed with the proper combination of "flats" to give a reflected sound content that will produce the desired depth illusion.

The motion-picture industry is rapidly developing the art of microphone movement for stereophonic recording where action and movement of camera are all-important. For other stereophonic pickup, such as music, radio plays or sound reinforcement, fixed microphone positions aided by some mixed-in special pickups will usually suffice. The regular microphones are deployed in front of the stage. If all action is at front stage, the outside microphones should be at the outside edges. However, to secure the illusion of action on a rectangular stage requires a greater stage width at the rear line than at the front (Fig. 6 in Ref. 27), and some compromise must be made; so the side microphones are usually placed somewhat inside the edges. This is particularly true of a two-channel system where a compromise between "hole-in-the-center" sound and well-spread sound must be effected. In this connection, a bridged center microphone is frequently used and does fill up the hole for center observing positions. However, it obtains this effect by adding sound to the side channels at advanced arrival time, thus aggravating the shift of the virtual source as the observer moves to the side of the auditorium.

After considerable experimentation, the microphones for the Philadelphia Orchestra recordings demonstrated by the Bell System in 1940 were suspended 10 ft above the stage and 5 ft inside the front row of musicians. The orchestra width was about 40 ft and the outside microphones were 28 ft apart. For small stages with actors, good results were obtained with a 12 ft square stage in a very dead room, using two microphones 9 ft apart and 5 ft from the front of the stage. In a rather reverberant medium-sized room a stage 15 ft wide by 6 ft deep, using three channels, with the microphones on 6-ft centers and 4 ft from the front line, proved satisfactory. In this case, note the shallow depth dictated by the reverberation in the room.

Directivity. Directive microphones can frequently be used to advantage. Since to produce an angular illusion it is necessary to generate intensity differences in the channels, a study of the geometry will show that greater movement is required at the rear of the pickup stage than at the front to produce a given angular impression. If the microphones are directive, greater intensity changes will occur as a source moves across the stage from the lobe of one microphone into that of another, and the rear line will be shortened. At the front line the directivity effect may be so great that the sound appears to recede between microphones. Experiment has shown that with moderate directivity, and by toeing in the lobes of the side microphones somewhat, an advantageous compromise between these two effects can be made and better overall coverage of a rectangular stage obtained.

This effect may be obtained with microphones of uniform directive properties, such as the cardioid types, or with the directivity only at high frequencies characteristic of a relatively large condenser or dynamic microphone at normal incidence. The latter will give accentuated directional effects with less change in overall loudness. Here directional effects are really quality changes. While in monophonic reproduction these quality changes would be objectionable, in stereophonic work the listener's fused impression consists of the contribution from several sources and the source is always in the direct lobe of one microphone. If the normal-incidence characteristic of the microphone is considered in overall system performance, the fidelity will remain high from all source positions.

The elimination of pickup from behind the microphones is a definite advantage in most cases. Obviously it eliminates noise. But it also eliminates part of the reverberation, and since most stages have more than the desired reverberation ratio for the physical depth, this is an advantage.

Reverberation. A pickup problem which has received little study as yet involves the adaptation of the reproduction to the listening room. The concept for reproduction in a theater or concert hall appears straightforward. To get good localization requires close pickup, and therefore the radiated sound approaches in quality the direct sound that would have been projected into the theater by a live (if gargantuan-voiced) performance. The theater then applies its own acoustical characteristics to the sound. In broadcasting and phonograph reproduction, however, listening is usually done in small, rather heavily damped rooms, and monophonic microphone techniques have been worked out to give a pleasing amount of reverberation from the pickup stage. Without doubt, some way will have to be found to produce a similar effect in stereophonic reproduction with the closer pickup required.

Bridged Microphones. Since channels are expensive and the complications grow with greater numbers, it is tempting to use bridged microphones to simplify the system. If this technique is used with restraint to gain additional realism in reproduction, it can be extremely useful. If it is used in the hope that it will be a cheap way of duplicating the performance of a more elaborate system, the results are bound to be disappointing. The tests reported in Fig. 1 of our original article[27] demonstrate this and are worth careful study. Discussion offered above explains why such techniques cannot be expected to duplicate real stereophonic channels.

An example of a useful application of the bridged microphone is its use to emphasize a small group of instruments in an orchestra, when the overall pickup is satisfactory in other respects. This was employed in the Hollywood Bowl demonstration[45] where one extra microphone was used continuously on the right channel, and others were employed during special parts of the performance. In monophonic systems multiple microphone pickup often leads to poor fidelity because of cancellation between the signals from the microphones in specific frequency regions. In stereophonic systems this effect is ameliorated because sound is fused from several sources.

When a solo instrument or voice is to be employed with an orchestra, separate pickup is very effective. The microphone should be arranged to pick up as little as possible of the orchestra, and the output should be mixed into the orchestra channels to give the localization desired. By far the best result will be obtained if the three-microphone triangular pickup described by Grignon[39] is used. The soloist will then be localized by substantially the whole audience at the desired location and the realism will be enhanced over a single microphone pickup.

Amplifiers

Amplifiers for use in stereophonic systems do not differ from those of monophonic systems except in number. The characteristics of the amplifiers in the various channels should be similar, and the gain should be stable so that no undesired level differences will occur. It is usually found desirable to have a ganged volume control which will adjust the overall level, and an individual control in each channel for balance or intentional unbalance settings. Similar provisions for quality-changing networks are desirable. If bridging systems are to be used proper networks and bridging amplifiers must be provided to insure that signals flow only in the desired directions, and inadvertent gain changes are not made during switching. It is also good practice to observe a poling convention throughout all channels, including the microphones and loudspeakers, although the channel spacings are so wide that only very low frequencies can be considered at other than random phase in one channel compared to another.

As a matter of economics, it is probably true that the added complication of stereophonic reproduction will be employed only for high-fidelity reproduction. Consequently the amplifier systems will require the same care in design and attention to detail that is required to secure high fidelity in monophonic systems.

APPLICATION TO RECORDING

The general principles of stereophonic sound apply to reproduction whether it is from recordings or from direct transmission by wire or radio. Recording has problems of flutter and maintenance of time differentials between channels peculiar to itself, and in general yields more severe technical problems in maintaining low noise and distortion. Yet it is certain that the great bulk of listening hours will be provided by recorded material. The effect of such distortions in stereophonic recording is therefore of great importance.

Distortion

The consensus of reported opinion in the literature is that stereophonic reproduction reduces the objectionableness of distortion and noise.[18] This unwieldy word is used because no test data are available to show whether the distortions become less detectable by the observer, or whether he is willing to overlook more distortion because of the increased pleasure of listening provided by stereophonic sound. Doubtless both reasons are true in part. The most outstanding example of the latter is the preference of observers for stereophonic sound, even though seriously degraded in frequency band.

Subtractive Type. It seems probable that distortions of a "subtractive" nature are actually less detectable. A dip in response of a single loudspeaker, or the equivalent caused by cancellation between two microphones on the same channel, will not be so noticeable if sound contributions from other channels not so distorted are being fused with the distorted signal.

Flutter. By similar reasoning, it seems probable that flutter will not be as noticeable on stereophonic reproduction. It is well established[46] that small frequency variations in the signal are turned into much larger amplitude modulations by the sharp resonances of the listening auditorium, and these are detected by the ear. Each channel will excite a different resonant pattern in the room. The fusion effect should therefore reduce the resultant modulation at the ear, with consequent reduction in flutter sensitivity.

Additive Type. It does not seem likely that the actual detectability of "additive" effects such as noise and distortion-product frequencies would be decreased by stereophonic reproduction, but their degrading effect does seem to be lessened. In monophonic reproduction any noise (distortion products are equivalent to noise) competes directly with the signal for attention whereas in stereophonic reproduction the directional illusion separates noises and program in space and allows the observer to concentrate more on desired sounds. Moir and Leslie[18] report a 12-db improvement in signal-to-noise ratio "due to the ears' steerable directivity pattern."

Channel Differences

Quality. For ideal results the quality of the various channels should be identical. Differences in quality will show up as differences from desired localization. On the other hand, a stereophonic effect will be preserved even with fairly large differences in quality. Consequently, in practical operation the attention now given to maintenance of uniform frequency response in high-fidelity monophonic systems will be adequate for the channels of stereophonic recording systems.

Level. The level difference between channels should be kept small, but the requirement does not seem inordinately difficult. A 2-db unbalance between the channels of a two-channel system — the most critical case — would shift the virtual source about 4 ft across a 45-ft stage.

Time. The requirement of time-identity of scanning position for the channels is considerably more stringent for true binaural than for stereophonic reproduction. Fifty microseconds difference would cause a 5° shift in binaural localization, corresponding to 0.7 mils misalignment for 15 ips track speed. However, for a two-channel stereophonic system a severe requirement might be 1 msec, corresponding to 15 mils misalignment for 15 ips track speed. This amount, equivalent to approximately 1-ft distance difference, would correspond to an actor moving from one side of a chair to the other, or to an auditor shifting from one seat to the next in the theater.

Dubbing

In the process of preparing a recording for release, a very important function is dubbing-in sound effects and music, or re-recording with altered quality or balance. In stereophonic recording there is the added requirement of proper position of the sound. When a single source must be given position, use is made of a bridged system and a "pan-pot." This is an arrangement of attenuators on a common control which will feed to each channel an intensity simulating the intensity it would have received if the original recording had been made with multiple microphones. The characteristic of the instrument built for the Auditory Perspective demonstrations of January 1934 is

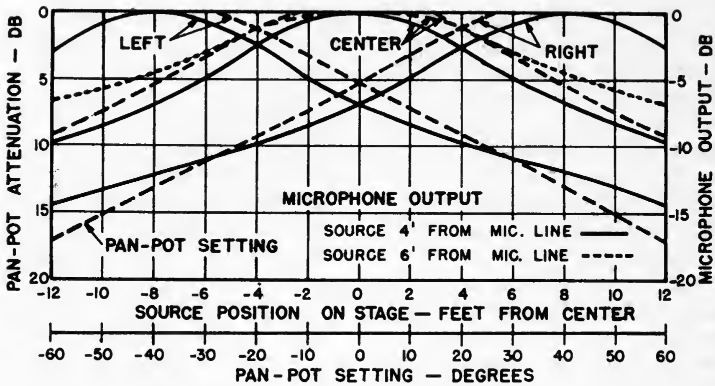


Fig. 5. Pan-pot characteristics. As a scource moves across a pickup stage, the direct sound microphone outputs vary as shown. The dashed line is the corresponding attenuation introduced by the pan-pot constructed for a 1934 demonstration.

shown by the dashed lines in Fig. 5. The control was made of three continuous-winding ladder volume controls modified with "bridges" for the sliders over parts of the angular range to give the flat portions of the curves. The solid lines of Fig. 5 show the variation in direct sound at each microphone for a source moving across a line 4 ft from the microphones, which are assumed 8 ft on centers.

It can be seen that this simple volume control scheme is a fair representation of the actual case. The dotted curve shows for comparison the variation in level for the center microphone when the source moves across a line 6 ft from the microphones. The difference between these curves emphasizes that the relationships vary for different stage depths, and in using a pan-pot the operator must adjust his settings to the desired effect. The curves also show the rather small level differences that exist. It will be seen that the pan-pot characteristic gives lower channel levels at "side" settings than the actual pickup. This is desirable to compensate for the absence of arrival-time and microphone directivity effects.

Disk Recording

The adaptability of tape- and film-recording methods to stereophonic sound is readily apparent, and these strip media are relatively unlimited as to number of channels. For two-channel recording, disk methods are also practicable. Two systems have been demonstrated. In one[47] two grooves are used in parallel, one starting near the outer edge and one near the middle of the recording area. Two reproducers are used. In the other[18,48,49] a single groove is used, with one channel recorded as a vertical and the other as a simultaneous lateral track. While the interaction or crosstalk between channels is relatively high, experiment has shown that a sufficient ratio for stereophonic work can be obtained.

CONCLUSION

Although stereophony is attaining a respectable age, much more information must be obtained before it can be said to rest on a foundation of quantitative relationships. It is hoped that this summary of present knowledge will stimulate the acquisition of this information, and in the interim will serve as a useful guide to those who must make recordings without waiting for complete theoretical understanding.

REFERENCES*

1. A. G. Bell, "Experiments relating to binaural audition," *Am. J. Otol.*, July 1880.
2. H. Fletcher, "Hearing, the determining factor for high fidelity transmission," *Proc. I. R. E.*, *30:* 266, June 1942.

3–10: A series of articles published in the *Philips Technical Review:*

3. K. de Boer and R. Vermeulen, "On improving of defective hearing," *4, no. 1:* 317, Nov. 1939.
4. K. de Boer, "Stereophonic sound reproduction," *5, no. 4:* 107, Apr. 1940.
5. K. de Boer, "Experiments with stereophonic records," *5, no. 6:* 183, June 1940.
6. K. de Boer, "Stereophonic recording on Philips-Miller film," *6, no. 3:* 80, Mar. 1941.
7. K. de Boer and A. TH. van Urk, "Some particulars of directional hearing," *6, no. 12:* 359, Dec. 1941.
8. K. de Boer, "The formation of stereophonic images," *8, no. 2:* 51, Feb. 1946.
9. K. de Boer, "A remarkable phenomenon with stereophonic sound reproduction," *9, no. 1:* 81, 1947.
10. R. Vermeulen, "Duplication of concerts," *10, no. 6:* 169, Dec. 1948.
11. G. W. Stewart, "The function of intensity and phase in binaural location of pure tones," *Phys. Rev.:* 425, May 1920.
12. R. V. L. Hartley and T. C. Fry, "The binaural localization of pure tones," *Phys. Rev.*, *18:* 431, Dec. 1921.
13. W. G. King and D. A. Laird, "The effect of noise intensity and pattern on locating sounds," *J. Acoust. Soc. Am.*, *2, no. 1:* 99, July 1930.
14. E. Meyer, "Stereoacoustics," *E.T.Z.*, *46:* 805, May 28, 1925.
15. K. Holt-Hansen, "Researches on the localization of sound," *Z. Psych.*, *120:* 209, 1931.
16. J. H. Shaxby and F. H. Gage, "Studies in localization of sound, a, the localization of sounds in the median plane," Special Report Series 166, Medical Research Council, London, circa 1933.
17. H. Wallach, E. B. Newman and M. R. Rosenzweig, "The precedence effect in sound localization," *Am. J. Psych.*, *62, no. 3:* 315, July 1949.
18. J. Moir and J. A. Leslie, "Stereophonic reproduction of speech and music," *J. Brit. I.R.E.*, *12, no. 6:* 360, June 1952.
19. F. M. Doolittle, U. S. Patent 1,817,177 (Aug. 1931) and U.S. Patent 2,126,370 (Aug. 1938).
20. E. H. Foley, U.S. Patent 1,589,139 (June 1926).
21. John M. Conly, "Hearing with both ears," *The Atlantic*, 89, Feb. 1953.
22. L. J. Sivian and S. D. White, "Minimum audible sound fields," *J. Acoust. Soc. Am.:* Apr. 1933.
23. J. P. Maxfield, "Some physical factors affecting the illusion in sound motion pictures," *J. Acoust. Soc. Am.:* July 1931.
24. J. G. Frayne and H. Wolfe, *Sound Recording*, John Wiley and Sons, New York, 1949.
25. V. O. Knudsen and C. M. Harris, *Acoustical Designing in Architecture*, John Wiley and Sons, New York, 1950.

26–31: Symposium on Reproduction in Auditory Perspective published in *Elec. Eng.*, *53:* 9, Jan. 1934; and in *Bell Sys. Tech. J.*, Apr. 1934.

* The list includes those mentioned in the text, plus others considered of interest. The listed publications also contain additional references.

26. Harvey Fletcher, "Basic requirements." (Reprinted in *Jour. SMPTE, 61:* 415–419, Sept. 1953.)
27. J. C. Steinberg and W. B. Snow, "Physical factors." (Reprinted in *Jour. SMPTE, 61:* 420–430, Sept. 1953.)
28. E. C. Wente and A. L. Thuras, "Loudspeakers and microphones." (Reprinted in *Jour. SMPTE, 61:* 431–446, Sept. 1953.)
29. E. O. Scriven, "Amplifiers."
30. H. A. Affel, R. W. Chesnut and R. H. Mills, "Transmission lines."
31. E. H. Bedell and I. Kerney, "System adaptation."
32–38: A Symposium on the Stereophonic Sound Film System, *Jour. SMPE, 37:* 331, Oct. 1941.
32. Harvey Fletcher, "General theory."
33. E. C. Wente, R. Biddulph, L. A. Elmer and A. B. Anderson, "Mechanical and optical equipment."
34. J. C. Steinberg, "Pre- and post-equalization of compandor systems."
35. W. B. Snow and A. R. Soffel, "Electrical equipment."
36. E. C. Wente and R. Biddulph, "A light valve."
37. E. C. Wente and A. H. Müller, "Internally damped rollers."
38. L. A. Elmer, "A non-cinching film rewind machine."
39. L. D. Grignon, "Experiment in stereophonic sound," *Jour. SMPE, 52:* 280, Mar. 1949. (For an augmented version of the same paper, see *Jour. SMPTE, 61:* 364–379, Sept. 1953.)
40. C. A. Lovell, U. S. Patent 2,261,628 (Nov. 1941).
41. W. B. Snow, U. S. Patent 2,137,032 (Nov. 1938).
42. A. J. Forman, "A new multiplex system for three dimensional sound," *Tele Tech, 12, no. 4:* 92, Apr. 1953.
43. "Cinerama," *International Sound Technician, 1, no. 1:* 4, Mar. 1953.
44. A. W. Colledge, *Western Electric Oscillator, 4, no. 11:* 1946.
45. "Paramount Night of Stars," Special Benefit Concert for Philharmonic Orchestra Continuance Fund, *Hollywood Bowl Magazine*, Aug. 17, 1936.
46. W. J. Albersheim and D. MacKenzie, "Analysis of sound film drives," *Jour. SMPE, 37:* 452, Nov. 1941.
47. E. Cook, "Recording binaural sound on discs," *Tele Tech, 11, no. 11:* 48, Nov. 1952.
48. Unpublished work at Bell Telephone Laboratories.
49. W. B. Jones, U.S. Patent 1,855,150 and U.S. Patent 1,855,151 (Apr. 1932).
50. W. L. Douden, U.S. Patent 2,124,030 (July 1938).
51. R. T. Friebus, U.S. Patent 2,114,049 (Apr. 1938) and U.S. Patent 2,249,606 (July 1938).
52. H. Fletcher, U.S. Patent 2,254,034 (Aug. 1941).
53. A. Rosenberg, British Patent 23,620 (1911).
54. Holst and de Boer, U.S. Patent 2,273,866 (Feb. 1942).
55. J. C. Steinberg and W. B. Snow, U.S. Patent 2,126,929 (Aug. 1938).
56. W. B. Snow, U.S. Patent 2,258,662 (Oct. 1941) and U.S. Patent 2,304,856 (Dec. 1942).
57. O. L. Guernsey, Jr., "The 3-dimension fever grips Hollywood," *New York Herald Tribune*, Feb. 15, 1953.
58. Perfect Transmission and Reproduction of Symphonic Music in Auditory Perspective: Forword, F. B. Jewett; Part I, The Demonstration, W. B. Snow; Part II, Transmission, H. S. Hamilton, *Bell Telephone Quarterly, 12, no. 3:* 156, July 1933.
59. E. H. Bedell, R. E. Crane, W. B. Snow and A. L. Thuras, "Technical problems of stereophonic reproduction," *Bell Laboratories Record, 12, no. 7:* 194, Mar. 1934.
60. Analytic Subject Index to Contemporary Acoustic Literature, Sec. 4.3, Binaural Hearing: Localization, *J. Acoust. Soc. Am., Cumulative Index, vols. 11 to 20:* 1948.
61. M. B. Sleeper, "Sound movement and dimensions," *FM-TV, 11, no. 1:* 48, Nov. 1951.
62. Raymond Spottiswoode, "Progress in three-dimensional films at the Festival of Britain," *Jour. SMPTE, 58:* 291, Apr. 1952.
63. Norman Jenkins, "The cash customers at the Festival of Britain Telecinema," *Jour. SMPTE, 58:* 304, Apr. 1952.
64. Otto Bixler, "A commercial binaural

recorder," *Jour. SMPTE, 59:* 109, Aug. 1952.
65. Harvey Fletcher, "Stereophonic recording and reproducing system," *Jour. SMPTE, 61:* 355–363, Sept. 1953.
66. John K. Hilliard, "Loudspeakers and amplifiers for use with stereophonic reproduction in the theater," *Jour. SMPTE, 61:* 380–389, Sept. 1953.
67. J. G. Frayne and E. W. Templin, "Stereophonic recording and reproducing equipment," *Jour. SMPTE, 61:* 395–407, Sept. 1953.
68. J. E. Volkmann, J. F. Byrd and J. D. Phyfe, "New theater sound system for multipurpose use," *Jour. SMPTE, 61:* 408–414, Sept. 1953.

Discussion

John G. Frayne (Westrex Corp.): Would the speaker tell us whether there's ever any possibility of duplicating the real stereophonic effect by using the artificial method of taking a monaural track and making it into stereophonic by manipulation of gain and equalization.

Mr. Snow: I don't think so, because by manipulation of the channels you do not duplicate all the effects which you can get on a real stage. As the speaker, let's say, walks across the stage you can get the actual effect of the intensity increase, you automatically get the effect of the arrival time with sound coming earlier from the nearest channel. You can use microphone directivity, if you use it with care, to enhance both of those effects; and it seems to me that, at least without something that I can't quite imagine in elaboration, it would be awfully hard for any one person to duplicate all these effects as he tried to twist some knobs. And, of course, there's another thing: no matter what you try to do in this way, you can do it for only one source at a time, if you're doing it artificially, whereas the actual pickup will handle any number of sources all at one time. My own feeling is that it is very unlikely that the completely artificial manipulation of channels will give you a real duplication of multiple-channel pickup at the original scene.

Dr. Frayne: In that case, would you say then that the industry is missing an opportunity of improved sound presentation by placing so much emphasis on the pan-pot method of producing stereophonic sound?

Mr. Snow: I would say that they ought to consider that something to get rid of as soon possible. It's something which can be used to advantage, I'm sure, in many situations; but I feel that it should be used only as a last resort, rather than as a first resort. It won't sound as good as the real pickup or the original.

Dr. Frayne: On the matter of the number of channels, I notice you say that three channels give a very good stereophonic effect. Now, in Cinerama, I believe, they use five stereophonic channels behind the screen and I am told by Cinerama engineers that they find a much better stereophonic effect by using five rather than three.

Mr. Snow: I use three for two reasons. One is that my personal experience has been with two or three and it makes the fundamentals easier to show. The fundamental principles I don't think would change with the number of channels, but I do feel that the number of channels depends upon the width of the stage, the width of the scene that you're going to cover and perhaps as a rule of thumb, you might say that a channel should not cover more than a width of 20 or 25 ft with a single channel. The cinerama screen is so much bigger than the 50-ft wide total that they needed more channels.

Dr. Frayne: In the case of CinemaScope, which uses in some cases a 65-ft screen, is it possible to cover that with three speakers?

Mr. Snow: I imagine that probably it will be thought so. I don't mean to sound as facetious as that. Actually, when you have a picture, you don't need to have as faithful sound localization as when you're only trying to reproduce an orchestra with nothing to look at, as I have usually done in my work. The picture certainly can complement the "monophonic" sound to some extent, as we're all well aware, since we've been getting along with one channel on any width screen up to now. As a matter of fact, I would think in a picture, up to the width that you spoke of, that would be satisfactory. I have no doubt, however, that more channels would be even more realistic, but it's certainly a matter of economics.

Dr. Frayne: What do you think of the auditorium speakers as adding to stereophonic effect?

Mr. Snow: That's something for the industry to decide now. I haven't had any personal experience with that. I have nothing against it. My feelings on stereophonic effects are that you manipulate the channels to get the effects you want. I was trying to point out the fundamentals that you have to preserve to get those effects, but I feel that when you get to the point of having auditorium speakers, and so on, it gets a little bit more in the showmanship angle than straight physics. And I'll leave that to the showman.

Edward S. Seeley (*Altec Service Corp.*): Do you believe it possible to recreate a location outside of the outermost speaker in a three-channel system?

Mr. Snow: Not acoustically, but with a picture I do think you can. However, there doesn't seem to be anything in the physics or physiology that I know of that would pull the sound past the outside loudspeaker just from the standpoint of localizing the sound with your eyes shut, but obviously if you have a picture, with a sound source that's outside the outside loudspeaker it's not very hard to imagine that the sound is pulled somewhat outside of the actual physical source of it. But you can see, from the standpoint of sound alone, that if you turned off all the channels but the one on the side that we're talking about, everybody would localize the sound right in that loudspeaker and there's nothing I can see that would make you pull it any further than that when the other ones are running.

Loren L. Ryder (*Paramount Pictures Corp.*): With respect to the remarks I am about to make, I will first say that my comments are not against stereophonic sound. Now with respect to what can be done by panning sound, we at Paramount have found that following some of the principles that were explained here but using phase displacement, rather than volume, we can more definitely control the placement of sound than by the volume difference between loudspeakers. We also find that equalization, as mentioned by the speaker, is a very strong control. We at Paramount have used displacement (phase shift) by as much as four and as high as seven sprocket holes in the control of sound placement. Having once established that type of sound placement, it makes little difference what volume is used from the three loudspeakers as far as the listener is concerned, and as far as his selection of a point source. Therefore, with such an arrangement, we can gain a proper directivity much further to the side of the theater and further down toward a side loudspeaker, than we have ever been able to obtain either by volume control or by classical stereophonic sound.

Mr. Snow: I'm very glad to hear of some practical experience along that line, because I certainly would expect that on the basis of the principles I was enunciating here; but unfortunately I have never been able to try it. Thanks very much for that comment.

Mr. Seeley: May I ask Mr. Ryder if his remarks apply to simultaneous sounds from distributed sources as well as to dialogue?

Mr. Ryder: My remarks apply to dialogue, music and sound effects. In the picture *Shane* there are sequences in which the violin section of the music is on the left-hand loudspeaker, the music base is on the right, dialogue is center screen, calls are heard from the left side of the screen and sound effects are moving back and forth.

We find no trouble in gaining proper placement of sound effects and we find no confusion when these sounds are ultimately reproduced in the theater. It seems to me that there is a great deal still to be learned in regard to the effective handling of sound when reproduced from three or more loudspeaker systems. For those who have not experimented with phase shifting, I recommend that they do so.

It is our feeling that there are a number of ways of gaining the same effectiveness to the audience. The real question is — which way is the simplest, least costly, and least subject to error and disturbing effects.

Richard H. Ranger (*Rangertone, Inc.*): I think that we all owe a debt of gratitude to Dr. Snow for this elucidation of these principles and I'd like to check again on what Mr. Ryder has just said, that timing has a terrific effect on directivity. We are indebted to Dr. Haas of Göttingen for work on this timing business, because he has elucidated this matter very intensively and confirms what has just been said. In other words, timing is of the utmost importance and you can actually get a curve or a correspondence, shall I say, between timing and intensity. In other words, as Mr. Ryder has just suggested here, you can move a subject across the stage just by timing; and you can also move it just by intensity. And you can do the corresponding thing of making them compensate each other. In other words, you can move the timing so as to make the apparent location move to the left, we'll say, and you can increase the intensity to hold it where it was. And you soon find, however, that when you do that the timing completely outweighs the intensity, so that actually the timing becomes in many ways the controlling factor. As to flutter and other quality factors, it has been my finding that they are entirely determined by the sound that you get first, or should I say that they are greatly determined by that. You can have considerable flutter, if you please, in the sound that comes later, and it will not affect the apparent quality at all. Timing and intensity, then, are terrifically important in these things. I don't quite go along with the statement that timing is the only essential, however. Perhaps Mr. Ryder did not intend to give that impression.

Mr. Ryder: It is certainly possible to control placement with intensity.

Col. Ranger: In fact, I feel that you can overdo the timing business, because you get a little bit of an uncertainty, if I might put it that way, when you get too much intensity from the wrong speaker, which you can do. You get a confusion of sound, so I feel that the answer is going to be a judicious use of the two to come up with the best quality.

Mr. Ryder: A further comment along the line of Col. Ranger's thoughts: if you use timing and equalization and volume, you have a very smooth complete control, and it's not as awkward to do as one would think. In this regard, we can refer to the picture *Shane,* which is largely handled by timing and not by volume. I should also comment that in all the work with respect to motion pictures where it is necessary to do much editing and cutting of motion pictures so that there is a change in sound placement on cuts, I personally favor a minimum movement of dialogue and a maximum use of stereophonic for punctuation in storytelling for effects and for music.

Walter Brecher (*Leo Brecher Theatres*): In connection with the finding that the number of channels to use with a wide screen should be based on a spacing of about 20 ft by channel, there are a great many theaters whose total width is in the neighborhood of 30 to 40 ft. It's my impression that there is a radius of illusion of approximately 15 ft which is centered on each speaker and in view of the acknowledgment that the visual pull does affect the illusion of location of sound source, does stereoscopic sound offer any substantial benefit for a theater of the dimensions that I have described?

Mr. Snow: I didn't mean to imply that. Let's put it another way. I meant that I felt that until people have actual data on it, that that was a fairly good rule of thumb as to the width where you might begin to consider that you might need more channels. But the stereophonic system will improve the reproduction in a living room where the loudspeakers are 5 ft apart or 12 ft apart, so that what I gave is in my opinion, a maximum width, and for anything smaller than that you can definitely get an improvement by using multiple channels. You might say, well, why not just use two channels? I believe that that would just make it more difficult from the pickup standpoint to get the effects you want, particularly when so much of the sound should come from the center of the stage for close-ups. When you have a third channel you can pretty nearly guarantee that for most of the seats in the auditorium. You're trying to build the illusion. With loudspeakers just at the sides, that's much harder to do.

Psychometric Evaluation of the Sharpness of Photographic Reproductions

By ROBERT N. WOLFE and FRED C. EISEN

Psychometric methods were used to evaluate the relative sharpness of a number of photographic reproductions in which sharpness was the only significant variable. Since sharpness is an observer's subjective impression of an aspect of picture definition, the methods for deriving sharpness values involve introspective processes and methods of quantifying these subjective impressions. Although no physical measurements of any aspect of the stimulus are involved in deriving sharpness values by the psychometric method, repeated evaluations showed that the scale values obtained are a reliable indication of the sharpness attribute of a photographic reproduction. Three methods of quantifying the judgment data were used, and the sharpness ratings obtained from all three were in good agreement with one another. Projected transparencies gave substantially the same results as paper enlargements. Attempts to correlate the sharpness ratings with physical measurements of some aspect of the developed image were not entirely successful; neither resolving power nor simple density relationships across an abrupt boundary between light and dark areas resulted in satisfactory correlations with sharpness ratings.

The sharpness of a photographic reproduction is a subjective concept associated with one of the impressions made on the mind of an observer when viewing a picture. Specifically, it is the impression produced by that aspect of picture definition which is affected by lens quality, lens focus, by the type of photographic material used, and by other factors in the photographic process. Since sharpness is a subjective concept, it cannot be evaluated directly by means of physical measurements, although a physical correlate may be found to exist. It is therefore necessary to employ psychometric methods to derive sharpness values. Psychophysical methods may be utilized subsequently to establish a correlation between sharpness and purely objective measurements of some aspect of the photographic image. Such an approach has been used by Baldwin[1] and by Mertz, Fowler and Christopher[2] in studies of television images.

Communication No. 1527 from the Kodak Research Laboratories, by Robert N. Wolfe and Fred C. Eisen, Kodak Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y. Reprinted from *Journal of the Optical Society of America, 43:* 914–922, Oct. 1953.

The present paper deals primarily with the psychometric evaluation of sharpness, and refers only briefly to a preliminary search for a physical correlate. The subject may be conveniently treated in three parts: (1) technique and precision of psychometric methods applicable to sharpness evaluations, (2) the effect of picture-making technique and test-picture subject matter on sharpness, and (3) results of a preliminary search for a physical or objective correlate.

Psychometric Methods

Since psychometric methods involve only introspective processes and methods of quantifying these subjective impressions, the reliability of the results obtained must be determined by repeating observations and by comparing different methods of quantification. To investigate the reliability of the psychometric methods involved in obtaining picture-sharpness ratings, a series of photographs which varied in sharpness were made. The test picture was the "patio" scene shown in Fig. 1. The negatives for these pictures were made by using ten different negative films, arbitrarily identified by numbers 1 to 10, each film being developed to give the same average density-log exposure (D-log E) gradient. These negatives varied in sharpness as the negative materials varied with respect to those qualities which influence the sharpness of recorded images. The negatives could themselves have been submitted to a group of observers for appraisal, but there were reasons for not doing so. In the first place, since most observers are not accustomed to viewing negatives, a more normal reaction can be expected from an examination of conventional positives; it is conceivable that sharpness impressions would be different when viewing a negative than when viewing a positive. Furthermore, the negatives, although matched in D-log E gradient over the exposure range of the picture, were not all of the same density level. These differences in density were compensated for in making the positives, in order to obtain prints that matched one another in tone reproduction. It was decided, therefore, that positive prints from each of the negatives should be used for the sharpness appraisals.

Positives of the ten negatives were made by (a) enlarging approximately four times onto photographic paper and (b) contact-printing onto lantern-slide plates. The contact-printing operation was carried out with a vacuum printing frame so that good transfer of the structural detail of the negative to the positive material was assured. The enlargements were made in a conventional enlarger, which was carefully focused for each negative. Two sets of enlargements were made to determine how accurately the print-making process could be repeated.

Sharpness Judging and Quantification of Data. In presenting the pictures to the observers, only very general instructions were given. No prompting or tutoring which might influence their reactions was permitted. The observers were all experienced in judging the quality of photographic reproductions but they were not aware of the devices that had been employed in altering the appearance of the pictures they examined. Each observer was requested to study the pictures and thereafter to express his opinion of their relative "sharpness." The specific term "sharpness" was always used, so the particular aspect of the reproduction that was appraised was the one which the word "sharpness" evoked in each observer's consciousness. Although no attempt was made to define the term, none of the observers appeared to be uncertain of its implications, and with very little hesitancy they all proceeded to make unqualified decisions.

Since there is no established unit of picture sharpness, all the results are

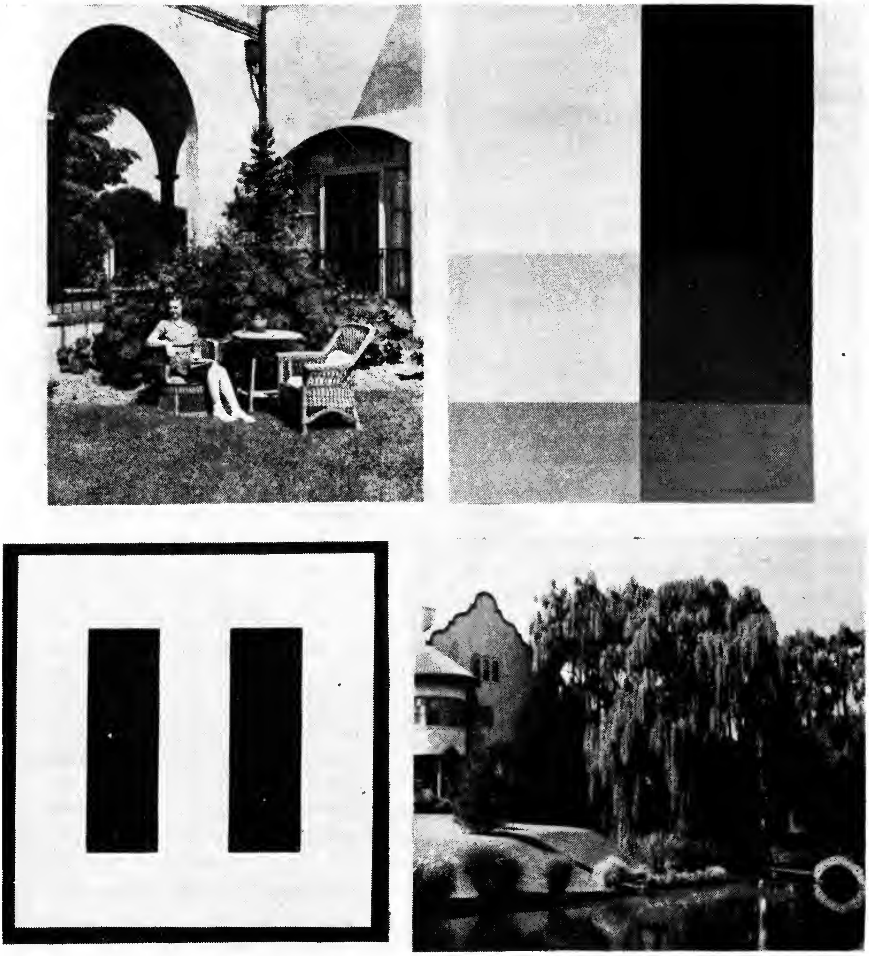


Fig. 1. Test objects used to investigate psychometric methods and effect of subject matter on sharpness judgments. "Patio" (above—left); "density patch" (above—right); "square" (below—left); "willow pond" (below—right).

relative. It follows, therefore, that sharpness evaluations can only be made by comparing one picture with another or with several others. Although an observer may have a definite impression that one picture is sharper than another, he normally does not appraise the difference numerically. The conversion of subjective impressions into numerical scale values is required for convenient utilization of the judgment data. This quantification of subjective impressions can be achieved by various methods, of which the following were considered in this work: (1) quantification by the observer himself, in which the observer is requested to express his impressions of sharpness in the form of numerical ratings; (2) quantification by statistical means after a number of observers have

Table I. Sample Data of Sharpness Ratings for First Set of Prints Obtained by Method of Observer Quantification.

Observer:	1		2		3		4		...20	
Negative material	As given	Adjusted	As given	Adjusted	As given	Adjusted	As given	Adjusted	Avg of 20 adjusted ratings	Prorated avg adjusted ratings
1	70	60	60	60	30	60	73	66	60.3	62
2	88	84	80	80	50	71.5	84	80	75.8	78.5
3	80	73	72	72	45	68.5	68	60	72.5	75
4	85	80	83	83	55	74	77	71	74.8	77
5	100	100	100	100	100	100	98	97.5	99.4	102.5
6	90	87	69	69	50	71.5	80	75	77.6	80
7	92	89	92	92	85	91.5	90	87.5	90.9	94
8	98	97.5	100	100	100	100	100	100	96.8	100
9	94	92	92	92	65	80	93	91	89.1	92
10	99	98.5	95	95	68	82	94	92.5	92.2	95

Equation for adjusting ratings to specified minimum value:

$$R' = 100 - \frac{(100 - R_s)(100 - R)}{100 - R_m}.$$

R = rating to be adjusted.
R' = adjusted rating.
R_m = minimum value as given by observer.
R_s = minimum value of adjusted ratings.

arranged the pictures in the order of their sharpness; and (3) quantification by the experimenter, who asks the observer to classify his impressions as "slightly sharper," "much less sharp," etc., and then arbitrarily assigns numerical values to each category. Regardless of which method is used, the numerical value of sharpness is nevertheless arbitrary and has no physical significance *per se*. The importance of the value is in the relationship it bears to other picture-sharpness ratings.

The first point to be determined was the reproducibility of the results, which could be taken as an index of the precision of the respective methods of evaluation. The first or observer-quantification method was studied by submitting the two sets of enlargements from the ten negatives, one set at a time, to twenty observers, who were asked to arrange the pictures in the order of their sharpness and to assign to each picture a numerical rating indicating the observer's opinion of its relative sharpness. The picture which an observer considered sharpest was always assigned a rating of 100, and each observer was free to assign the ratings for the remaining pictures according to his impressions of their sharpness. However, each observer's ratings for each set of prints were later adjusted so that the least sharp picture had a rating of 60 for that particular observer. The same ratio of rating differences was maintained in making this adjustment, while the sharpness values were brought to a common scale. The adjusted ratings of the twenty observers were then averaged, and the averages were prorated to make the rating for picture No. 8 equal to 100. Sample data to illustrate this procedure, as used for the first set of prints, are shown in Table I. A graphical comparison of the ratings obtained from the two sets of prints is shown by graph A in Fig. 2.

The second or statistical method of quantification was then applied to the data obtained from the judging of the enlarged prints. In this method, the

Table II. Derivation of Sharpness Ratings From Order Numbers.

Negative material	1	2	3	4	5	6	7	8	9	10
Observer					**Order numbers**					
1	10	7	9	8	1	6	5	3	4	2
2	10	7	8	6	1.5	9	4.5	1.5	4.5	3
3	10	7.5	9	6	1.5	7.5	3	1.5	5	4
4	9	6	10	8	2	7	5	1	4	3
•										
•										
•										
20										
$P = \frac{\Sigma r_1 - 0.5N}{nN}$	0.943	0.672	0.748	0.725	0.078	0.668	0.316	0.145	0.379	0.286
t	1.58	0.45	0.67	0.60	−1.42	0.43	−0.48	−1.06	−0.31	−0.57
$-(t - 1.58)$	0	1.13	0.91	0.98	3.00	1.15	2.06	2.64	1.89	2.15
Prorated 100 ~ 2.64	0	43	34.5	37	113.5	43.5	78	100	72	81.5
Adjusted 62 ~ 0	62	78	75	76	105	78.5	91.5	100	89	93

P = proportion of the area under the normal distribution curve.
r_1 = order number.
N = number of observers.
n = number of pictures.
t = ordinate of normal distribution curve determined by the proportion of the area under the curve.

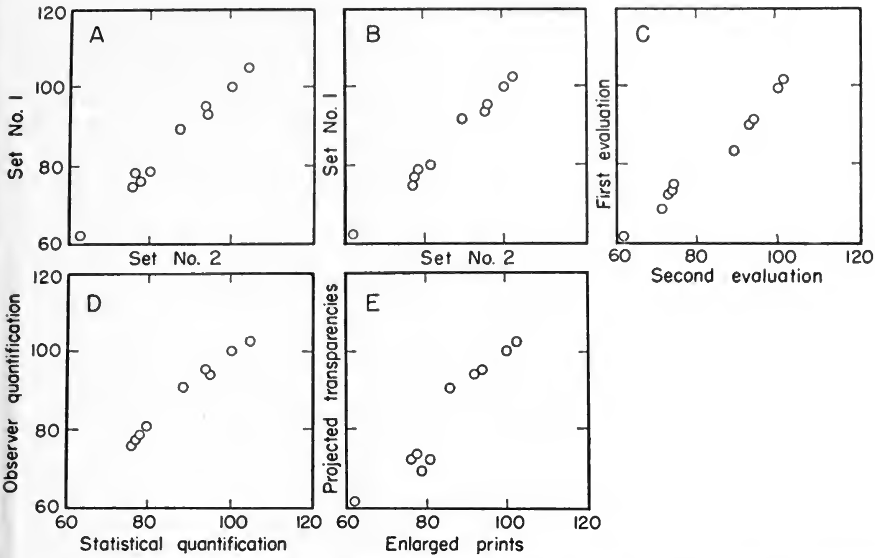


Fig. 2. Comparison of relative picture-sharpness ratings made under various conditions: A, two sets of enlargements from same negatives, observer quantification; B, enlargements from same negatives, statistical quantification; C, two observations at different times, same projected transparencies, paired comparison; D, same enlargements, observer quantification as ordinates, statistical quantification as abscissas; E, same negatives, projected transparencies by paired comparison as ordinates, enlargements by observer quantification as abscissas.

numerical ratings assigned by the observers were not needed, since only the ranking data were used. To derive sharpness ratings from the order numbers, Guilford's method based on a composite standard[3] was used. The scale values obtained by this method depend upon the number of times each picture was ranked in each position in the 1 to 10 range. When an observer selected two or more pictures equal in sharpness, each of the equally ranked pictures was given an order number which was the average of as many successive order numbers as there were equally ranked pictures. For instance, if, after three pictures had been arranged in a descending order of sharpness, the next two pictures were considered equal in sharpness, the order number that would be assigned to each of these two pictures would be 4.5, the average of rank positions 4 and 5. The procedure used to derive sharpness ratings from the order numbers is illustrated in Table II. The final ratings were adjusted to be 62 and 100 for pictures Nos. 1 and 8, respectively, of both sets, which were the values obtained in the preceding method of quantification. The ratings obtained for the two sets of enlargements are plotted against each other as graph B of Fig. 2.

The third method of quantification was employed in obtaining numerical ratings of sharpness for the positive transparencies made from the same ten negatives. In this case, the psychometric data were derived from sharpness appraisals made by a "paired-comparison" procedure. The observers were requested to view two pictures

Table III. Sample of Paired-Comparison Data. Slide No. 7 Compared With Each of the Others.

Film		1	2	3	4	5	6	7	8	9	10
Observer	A	−0.3	−0.2	−0.1	−0.2	+0.1	0.00		−0.1	0.00	0.00
	B	−0.3	−0.1	−0.1	−0.1	+0.2	−0.2		+0.1	0.00	+0.2
	C	−0.3	−0.1	−0.2	−0.1	+0.2	−0.1		+0.1	0.00	+0.1
	D	−0.2	−0.1	−0.1	−0.1	+0.2	−0.2		+0.1	0.00	0.00
	E	−0.2	0.00	+0.1	−0.1	+0.2	−0.1		+0.1	−0.1	+0.2
	F	−0.2	−0.2	0.00	−0.1	+0.2	0.00		0.00	+0.1	+0.1
	G	−0.2	−0.2	−0.1	−0.1	+0.1	0.00		0.00	0.00	0.00
	H	0.00	−0.1	+0.1	0.00	+0.1	+0.1		+0.1	+0.2	+0.2
	I	−0.2	−0.1	−0.1	0.00	+0.2	0.00	Comparison	+0.2	+0.1	+0.1
	J	−0.2	−0.1	−0.2	−0.2	+0.2	−0.1	Slide	+0.2	+0.2	+0.2
Avg.		−0.21	−0.12	−0.07	−0.10	+0.17	−0.06	0.00	+0.08	+0.05	+0.11
Rel. Log Sharpness		1.79	1.88	1.93	1.90	2.17	1.94	2.00	2.08	2.05	2.11
Rel. Sharpness		62	76	85	79	148	87	100	120	112	129
Prorated		52	63	71	66	123	72	83	100	93	107

projected simultaneously on a screen by two slide projectors. A group of ten observers viewed the pictures and made individual judgments. Two assistants located very close to the screen operated remote-control focusing devices for maintaining the best possible focus during judging. Each of the ten positives was compared with every other positive twice, once in each projector, in order to eliminate any difference in the quality of the projectors. Thus, a total of ninety comparisons was made. The observers were asked to give their impressions of the comparative sharpness of the two adjacent pictures in terms of the following seven ratings:

1. Picture A much sharper than Picture B;
2. Picture A sharper than Picture B;
3. Picture A slightly sharper than Picture B;
4. Picture A equal in sharpness to Picture B;
5. Picture A slightly less sharp than Picture B;
6. Picture A less sharp than Picture B; or
7. Picture A much less sharp than Picture B.

Numerical values of 0.3, 0.2, 0.1, 0.0, −0.1, −0.2 and −0.3, respectively, were arbitrarily assigned to each of these qualitative ratings. These numbers were treated as increments in a scale of logarithmic sharpness ratings. The final scale values were antilogarithms of the scale values derived from these numerical increments.

After ninety comparisons were made, numerical sharpness values were assigned, on the basis of the observers' ratings, to each comparison for each observer. For example, if an observer indicated that he considered Picture A to be slightly sharper than B, then for that comparison, Picture A was assigned a value of 0.00 and Picture B was assigned a value of −0.10. The values determined by the ten observers for each comparison were averaged and used as a basis for calculating ninety relative sharpness ratings which were prorated to make the rating for picture No. 8 equal to 100. Table III illustrates this part of the procedure, using data obtained from comparisons No. 73 to 81, for which picture No. 7 was used in all cases as one member of the pair. From the ninety comparisons made, each of the other nine pictures had ten separate sharpness ratings relative to that of the positive from negative No. 8, either by direct or indirect comparison. These ten relative sharpness ratings were averaged and the resulting values were taken as the picture-sharpness ratings of the positives relative to the positive from negative No. 8.

The same positive transparencies were rated again a few weeks after the first evaluation, using the same procedure and the same observers. The two sets of ratings were adjusted to make picture No. 1 rate 62 as before, No. 8 remaining at 100, and the two sets are compared as graph C of Fig. 2. A good correlation is indicated.

It is of interest to compare the results obtained by the various methods of evaluating the positives. As pointed out previously, graphs A and B of Fig. 2 show that the two sets of enlargements gave results that are in good agreement with each other for both the observer-quantification and the statistical-quantification methods. Graph C shows that the two sets of transparencies compared by pairs gave results that are in agreement with each other for the experimenter-quantification method. The mean values of the ratings obtained for the two sets by the first and the second methods are compared by graph D, which shows that the two methods are in good agreement. The results obtained from the third method as compared with those obtained from the first two involve differences in the methods of printing the positives and the materials used for them in addition. These results will be discussed below.

Effect of Picture-Making Technique and Test-Picture Subject Matter on Sharpness

Since the paper prints judged for sharpness as described in the preceding section were made by optical enlargement of the negative while the positive transparencies were made by contact-printing the same negatives, a comparison of the ratings obtained from the two types of positives will give some information as to the effect of picture-making technique on sharpness, even though different psychometric methods were used to obtain the ratings. The averages of the sharpness ratings obtained for the transparencies on the two separate occasions were computed, as were the averages of the ratings obtained by the observer-quantification method for the two sets of enlargements. These averages are plotted against each other as graph E in Fig. 2. The departures from a straight line are noticeably greater in this case than in the others, as would be expected considering that another variable has been introduced, but the correlation is still fair. This indicates that the ratings obtained by judging the sharpness of the pictures either as projected transparencies or as paper prints, following any of the procedures described in this report, give a reliable indication of the relative sharpness obtainable with these negative emulsions developed and printed according to the procedures adopted in this work.

Since all the preceding evaluations were made on appraisals of pictures having the same subject matter, it was of interest to determine whether sharpness ratings are dependent upon the composition of the test object used. Therefore, a test was designed for the purpose of determining how much effect, if any, the test-picture subject matter might have on the sharpness evaluation of the pictures.

Six negative-type films, which were expected to produce pictures of different sharpness, were exposed to each of the

Table IV. Sharpness Ratings for Four Test Objects.

Negative material	Ranks converted to relative scale values (ratings)			
	Density patch	Willow pond	Divided square	Patio scene
11	100.0	100.0	100.0	100.0
5	95.2	90.6	93.3	93.7
12	93.3	89.9	88.2	90.0
13	89.3	89.4	85.2	87.2
3	82.5	85.3	82.4	84.8
1	80.0	80.0	80.0	80.0

four test objects shown in Fig. 1. Two of the test objects were the continuous-tone pictures entitled "patio" and "willow pond," while the other two were geometrical patterns with well-defined boundaries, one called the "density-patch" test object and the other the "divided-square" test object. The two picture test objects and the density-patch test object had density scales of approximately 1.30, whereas the divided-square test object was composed of a clear area on a background of density greater than 3.0.

Six negative materials were exposed in contact with positive transparencies of the four test objects and were developed to give the same average *D*-log *E* gradient over an exposure range of approximately 1.30. The divided square was exposed to give a maximum density of approximately 1.50, which was as high as, or higher than, the maximum densities obtained in the other test-object reproductions. The negatives were enlarged five times on suitable enlarging paper to produce positives matched in tone reproduction.

The four sets of six prints were each submitted, one set at a time, to ten observers who were asked to arrange the prints in the order of their sharpness. The sharpness ratings derived from the order numbers of the ten observers by Guilford's method based on a composite standard[3] are shown in Table IV. These ratings, or scale values, have been adjusted to make the rating of the sharpest print equal to 100 and the rating of the least sharp print equal to 80 for each test object. This adjustment is permissible because the terminal points and the scale unit of sharpness ratings derived in this way can be arbitrarily assigned.

Examination of Table IV shows that the negative materials are placed in the same order by the sharpness ratings for each test object, but that the magnitudes of the ratings for a particular negative film vary among the different test objects. This means that the changing of test objects does affect the sharpness ratings but that the effect is small compared with the variation in sharpness ratings caused by differences in the negative materials used in this test. It should be emphasized that even the differences in sharpness among the prints from the different negative materials is small. A statistical examination of the psychometric data indicates that a difference in sharpness represented by about five units of the scale values in Table IV is just significantly noticeable (i.e., a print rated at 100 will be considered sharper than a print rated at 95 in about two-thirds of the judgments). Thus, a difference in sharpness rating caused by a difference in test-object composition can be considered to be quite small and capable of affecting the relative rating of a pair of prints only when the difference in sharpness between prints is so small that it is just noticeable; the most significant variable is the negative material. A summary of the treatment of the data by the analysis of variance leading to these conclusions is given in the Appendix.

The conclusions are based on the appraisal of prints made from normally exposed negatives and do not necessarily apply for overexposed negatives. It is conceivable that when high densities and halation effects are involved, there might be some types of test objects that would give sharpness values radically different from others.

Search for a Physical or Objective Correlate of Sharpness

With the reliability of the subjectively evaluated sharpness values established, a search for a physical correlate was undertaken. For this phase of the investigation, pictures of the "willow pond" were obtained in which the sharpness was varied by (a) making negatives on a single type of film and varying the position of the film with respect to the focus of the lens in the camera, and (b) using ten different types of film in preparing the negatives from which positives matched with respect to tone reproduction were made, the camera focus being kept constant.

For the first set of pictures, exposures were made to (a) the "willow pond" test object, (b) a high-contrast, three-line resolving-power test object, (c) a similar test object of low contrast, and (d) a single-edge test object. The luminance ratio between characters and background of the high-contrast resolving-power test object was over 1000, while for the low-contrast one it was 1.6. Each of the four test objects was exposed at the same twelve focal positions of the lens. The test objects were restricted to a small field angle to avoid complications arising from field aberrations. Exposure and processing conditions were chosen to give pictures of good tone reproduction, and these same conditions were used for the resolving-power exposures and for the single-edge exposures. Positives of the picture negatives were made in the form of paper prints, and they were evaluated for sharpness by the observer-quantification method described above. The resolving-power values were determined by a visual examination of the negatives, using a suitable viewing magnification, and the density-distance curves were obtained from microdensitometer traces across edges in the negatives.

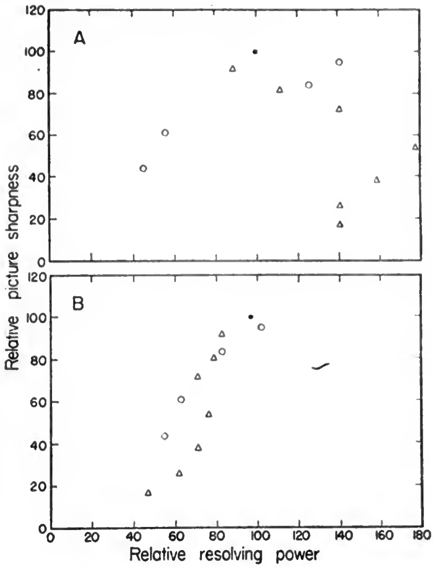


Fig. 3. Comparison of relative picture sharpness with relative resolving power for lens-focus series: A, high-contrast resolving-power test object (luminance ratio over 1000); B, low-contrast test object (luminance ratio, 1.6). O Inside focus; ● at focus (point of maximum sharpness); △ outside focus.

The same "willow pond" and single-edge test objects were used for the series in which the negative material was varied. The resolving-power exposures, however, were made in a camera especially designed for the purpose, as described later. The picture negatives were printed on a positive film and evaluated for sharpness by the paired-comparison method already described.

Resolving Power Compared With Sharpness. Although the measurement of resolving power cannot be classified as a purely objective procedure since it involves the visual examination of the images, such measurements are included in this investigation because it is sometimes as-

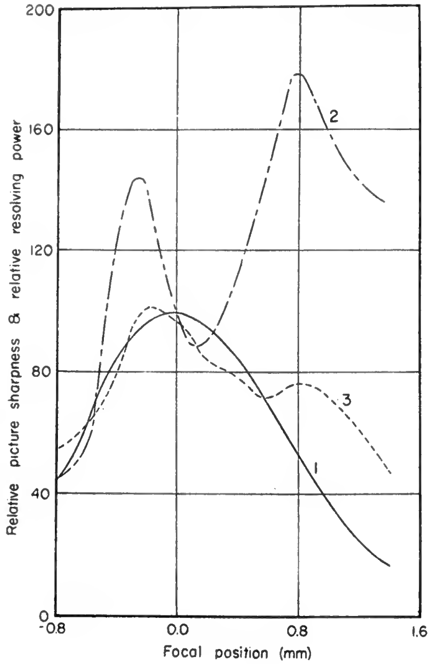


Fig. 4. Relative resolving power and picture sharpness as a function of focal position: 1, sharpness; 2, resolving power, high-contrast test object; 3, resolving power, low-contrast test object. Origin of abscissas at point of maximum sharpness.

sumed that resolving power is the significant measure of the performance of a reproducing system with respect to image definition.

For the lens-focus series, relative picture sharpness is plotted as a function of resolving power in Fig. 3, graphs A and B being for the high- and the low-contrast test objects, respectively. These same data are plotted as functions of the position of the film along the lens axis by curves 2 and 3 in Fig. 4. Curve 1 represents relative sharpness, and the abscissas represent the distance in millimeters from the position of maximum sharpness. It is striking that the position of maximum resolving power for the high-contrast test object is approximately one millimeter from the position of maximum sharpness. The maximum for the low-contrast test object is closer but still is not coincident.

To determine why the position of maximum resolving power does not coincide with the position of maximum sharpness, a point source was photographed under the same conditions as were employed in making the picture negatives. Reproductions of these photographs are shown in Fig. 5. These photographs are the same ones that were published by Herzberger[4] a few years ago except that the focal positions

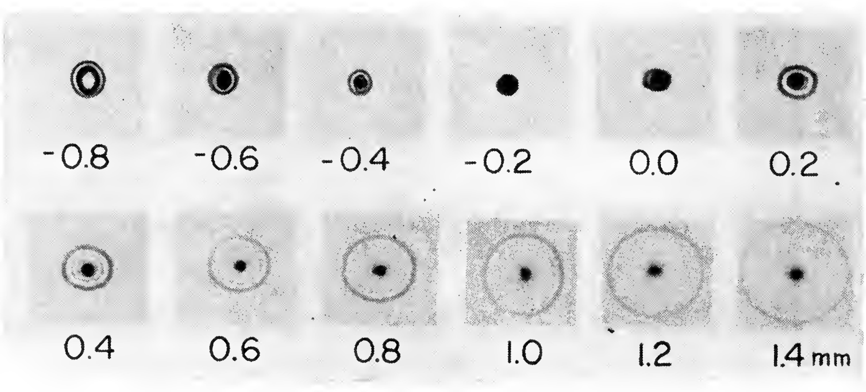


Fig. 5. Images of point source at different focal positions. Positions correspond to abscissas of Fig. 4.

have been labeled anew to correspond with the abscissas of Fig. 4. At the −0.8-mm focus position, which gives low resolving power and poor sharpness, the image consists of circular rings with no central core. These rings form into a fairly compact core at the 0.0-mm focus position, where sharpness is at a maximum and near where one of the resolving-power maxima occurs. The second resolving-power maximum occurs at a focal position of 0.8, where the point-source image consists of a small, sharp nucleus surrounded by an extensive circular blur or haze. This distribution of energy results in the formation of an image of the resolving-power test object in which the lines can be seen distinctly although they are surrounded by an extensive halo. This halo does not interfere with the distinguishability of parallel lines in the images of the resolving-power test object, but it does degrade the edge characteristics of other image elements to such an extent that pictures made at this focal position are distinctly inferior to those made at the position giving maximum sharpness.

The resolving power of the ten films used to make the sharpness series was based on exposures made in a resolving-power camera[5] with a high-contrast, three-line test pattern. Each film was developed as it was for the picture exposures. The maximum resolving-power values obtained from an exposure series are plotted in Fig. 6 as a function of the sharpness ratings; graph A is for a high-contrast test object while B is for a low. Both sharpness and resolving power are expressed in relative terms. It is evident that the correlations are not good enough to establish a psychophysical relationship. The following factors may be responsible for the lack of a better correlation:

(1) The resolving-power values represent measurements made on images in the negatives while the sharpness evaluations were obtained from the positives.

(2) Resolving power is a measure of

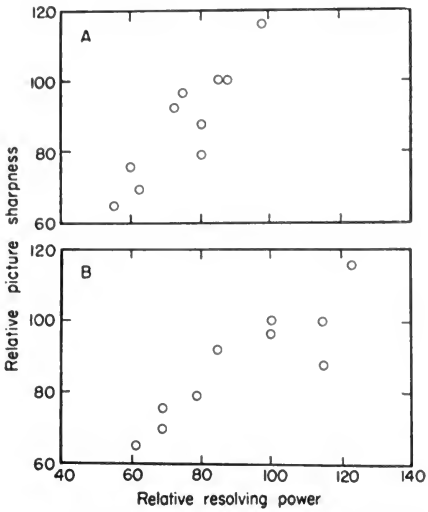


Fig. 6. Comparison of resolving power with picture sharpness, negative-film series: A, high contrast; B, low contrast.

the least distance between adjacent detail elements which can just be discerned as separate. This limiting distance is related to, but is not a measure of, the sharpness of the detail elements as their proximity to one another decreases.

(3) The resolving-power test images were not similar to the picture negatives in density scale.

Gradients Compared With Sharpness. Since an observer viewing a photograph gets his impression of sharpness largely from the way that the edges of objects are reproduced, the variation of density across the exposure of an edge is an obvious physical measurement that should be investigated. It seems likely that some aspect of such a density-distance curve derived from photographic images of a knife-edge test object would produce values which would correlate with the sharpness values obtained subjectively. This idea is not new; Ross[6] and others before him have discussed certain features of the density-distance

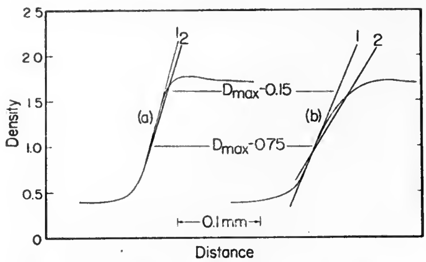


Fig. 7. Examples of density-distance curves obtained at position for (a) sharp picture (0.0 mm) and (b) relatively unsharp picture (−0.6 mm). Straight lines represent (1) maximum gradient and (2) 0.15,0.75–average gradient.

curve in their relation to sharpness, which he defined as "primarily a sensation."* But, although he admitted that such features as the maximum gradient cannot be taken as a measure of sharpness without experimental proof, he offered no subjective data.

For this work, microdensitometer measurements were made across the boundary between the high-density area and the low-density area resulting from exposures to the single-edge test objects. The curves obtained in the lens-focus series at a focal position producing a sharp picture and at a focal position producing a relatively unsharp picture are shown in Fig. 7. Several aspects of the curves obtained at each focal position were measured in an attempt to find a set of values which would correlate well with the sharpness ratings. Figure 7 shows two of the gradients that were measured, (1) the maximum gradient, and (2) an average gradient between a point 0.15 density units less than maximum density and a point 0.75 density units less than maximum density. These gradient values can be compared with the picture-sharpness values in Tables V and VI. Column 3 of Table V relates to the maximum gradient for the lens-focus series while the last column relates to the 0.15,0.75–average gradient. Columns 3 and 4 of Table VI relate respectively to the same quantities for the negative-film series. The last column relates to the values of maximum gradient across the same boundary in the positives. The values in each table have been adjusted so that they are equal for the sharpest and the least-sharp picture condition.

An examination of the data for the lens-focus series in Table V shows that the maximum-gradient criterion does not produce values in the same order as the picture-sharpness values, while the 0.15,0.75 – average - gradient criterion does produce values in almost the same order as the sharpness ratings. However, for the negative-film series data shown in Table VI, none of the gradient measurements produces values in the the same order as the picture-sharpness values. Although the 0.15,0.75–average gradient criterion appears to correlate fairly well with sharpness in the lens-focus series, where the sharpness differ-

Table V. Picture Sharpness and Gradient Values for Lens-focus Series.

Focal position (mm)	Relative picture sharpness	Relative maximum gradient	Relative 0.15,0.75–avg gradient
−0.8	44	62	26
−0.6	61	45	44
−0.4	84	53	69
−0.2	95	69	98
0.0	100	100	100
0.2	92	75	83
0.4	81	44	68
0.6	72	49	51
0.8	54	48	40
1.0	38	31	28
1.2	26	25	23
1.4	17	17	17

* Despite his definition, he followed the contemporary practice of applying the term "sharpness" to the density-distance curve itself.

Table VI. Picture Sharpness and Gradient Values for Negative-Film Series.

Negative material	Relative picture sharpness	Relative maximum gradient (negative)	Relative -0.15,0.75-avg gradient (negative)	Relative maximum gradient (positive)
1	60	60	60	60
2	65	56.5	56	64.5
3	69.5	54	69	53
4	72	65	64.5	76
5	79	94	86	89
6	82	99	88	94
7	85	97	94.5	94.5
8	88	106.5	105.5	94.5
9	88	102.5	112	96.5
10	100	100	100	100

ences are relatively large, it does not seem to correlate so well in the negative-film series, where the sharpness differences are much smaller. This may mean that this particular average-gradient criterion is not satisfactory for detecting small sharpness differences, or it may mean that the sharpness changes caused by film variations are of a different nature from the sharpness changes caused by variations in focusing. From Fig. 7 it is obvious that the maximum gradient bears no relation to the shape of the curve, and this shape could be altered considerably without affecting the value of the 0.15,0.75-average gradient. Thus, changes in the toe and shoulder might not affect the values of this average gradient appreciably, but it is quite likely that they would greatly affect an observer's estimate of sharpness. Since this work was done, the sharpness values obtained from it have been used by Higgins and Jones[7] to develop a criterion that has been described elsewhere. The values given in the present paper are the unpublished data to which these writers refer.

Conclusions

The results of this investigation indicate that sharpness is a definite aspect of picture quality which can be reliably evaluated by psychometric methods. Either projected transparencies or paper prints can be evaluated for sharpness by the methods described in this paper. The relative sharpness values thus obtained do not appear to be dependent to any great extent on the method used to quantify the subjective impressions, nor does the composition of the test object have much effect on the sharpness ratings. Although the preliminary attempts described herein to correlate sharpness ratings with physical measurements of some aspect of the developed image were not completely successful, the ratings themselves have been found useful in other studies of the subject.

References

1. M. W. Baldwin, Jr., "The subjective sharpness of simulated television images," *Proc. I.R.E.*, *28:* 458–468, 1940.
2. Pierre Mertz, A. D. Fowler and H. N. Christopher, "Quality rating of television images," *Proc. I.R.E.*, *38:* 1269–1283, 1950.
3. J. P. Guilford, *Psychometric Methods*, McGraw-Hill, New York, 1936; pp. 250–251.
4. M. Herzberger, "Light distribution in the optical image," *J. Opt. Soc. Am.*, *37:* 485–493, 1947.
5. F. H. Perrin and J. H. Altman, "Photographic sharpness and resolving power. II. The resolving-power cameras in the Kodak Research Laboratory," *J. Opt. Soc. Am.*, *41:* 265, 1951.

6. F. E. Ross, *The Physics of the Photographic Image*, Van Nostrand, New York, 1924; pp. 124–143.
7. G. C. Higgins and L. A. Jones, "The nature and evaluation of the sharpness of photographic images," *Jour. SMPTE*, *58:* 277–290, Apr. 1952; *PSA Jour.* (Phot. Sci. and Technique), *19B:* 55, 1953.

APPENDIX: Analysis of Variance, Sharpness Rank Numbers; 10 Observers, 6 Emulsions, 4 Test Objects.

Source of variance	Degrees of freedom	Sum of squares	Mean squares	Variance ratio	Components of variance	Standard deviation
Materials	5	546	109.2	91***	2.69	1.64
Materials × observers	45	31	0.69	1.53°	0.06	0.24
Materials × test objects	15	18	1.20	2.67**	0.07	0.27
Residual	174	78	0.45		0.45	0.67
Total	239	673			3.27	1.81

Because of the nature of the data used, there is no variability caused by the observers, by the test objects, nor by the observers × test objects. Therefore, the analysis can be considered a "doubly incomplete three-factor analysis: one factor with double-order replication." The degrees of freedom of the observers, the test objects, and the observers × test objects are pooled with the residual. The effect of changing the test objects is revealed by the material × test object interaction.

Random Picture Spacing With Multiple Camera Installations

By R. I. WILKINSON and H. G. ROMIG

When several high-speed cameras are operated simultaneously, but independently, it is possible that the aggregate of pictures obtained will satisfactorily cover the space between the pictures provided by any one camera. This paper gives a method for estimating the probability that the longest interval without a picture will not exceed a selected value.

Occasions arise when the rate of taking pictures with the fastest available motion-picture camera is insufficient to examine the characteristics of a rapidly moving object or phenomenon. One solution would be to synchronize two or more cameras out of phase so as to obtain suitably spaced pictures intermediate to those provided by a single machine. This would usually be an expensive and time-consuming procedure.

An alternative solution is to set up two or more high-speed cameras at the same location and operate them quite independently hoping that by chance from the aggregate of pictures so obtained a sufficiently "continuous" record of the sequence of events will result. What kind of coverage can be obtained by this procedure, and in particular what quantitative statement can be made regarding the adequacy of the coverage of the interval between the pictures provided by one camera? Since no particular subspacing of the pictures can be guaranteed with such a random timing arrangement, any description of the coverage must be made in terms of probabilities.

What, for instance, is the probability that with m cameras operating at random synchronization, there will be no more than c time intervals between pictures, which exceed a fraction, r, of a selected picture interval I of any one camera? How many cameras need be set up to provide a high degree of assurance that the longest picture spacing in such an interval will be less than i sec? How much improvement in the picture definition can be obtained by doubling the number of cameras? If the probability of finding no spacings greater than i sec is doubtfully acceptable, will permitting one interval to be as large as $2i$ improve the assurance sufficiently to give a satisfactory program? These and numbers of allied questions may be posed by

Presented on October 8, 1952, at the Society's Convention at Washington, D.C., by R. I. Wilkinson (who read the paper) Bell Telephone Laboratories, Inc., 463 West St., New York 14, and H. G. Romig, Hughes Aircraft Co., Culver City, Calif. (This paper was received December 3, 1952.)

Ed Note: Due to the extensive nature of the discussion, the Chairman of the Board of Editors sought clarification and editing, a service which C. D. Miller has kindly performed.

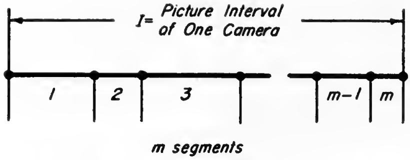


Fig. 1. Random division of a line in m segments.

those in charge of photographing very fast moving events. The theory of probability can give us their answers under certain simple assumptions as to the conditions of the experiment.

The most precise probability statements can be made in regard to the picture spaces which occur in some interval I, the length of the frame interval for a single camera. Such an interval can be chosen at random or designated by an event or criterion not depending on an examination or knowledge of the current picture spacing configuration. Certain useful conjectures can also be made concerning the picture spacings over a succession of I intervals. The limited first problem will be studied in considerable detail and followed by some comments on the more general situation.

Suppose m constant-speed cameras in random synchronization are taking high-speed pictures of some rapid phenomenon. In Fig. 1 the length of the heavy line is I sec and represents the time between successive pictures taken by camera No. 1. The picture instants of the other m-1 cameras might be as indicated by the heavy dots strewn "at random" along the length I. (The exposure time is considered to be short compared with the picture interval I.) We shall first determine the probability that none of the segments between the dots will exceed a length of i sec, and then solve the more general problem that exactly c segments will exceed i sec.

Imagine the picture interval I to be made up of a great number n of much smaller unit intervals, and that measured in these intervals, the permissible picture spacing i is s units long. Our problem now resolves itself into the geometrical one: When a line n units long is divided arbitrarily into m segments, what is the probability that exactly c segments will be s units long or longer?

A Mathematical Analogy*

Consider the possible composition of any one segment of the picture interval I, say the first one. Its length may conceivably vary from 0 to n units. (In the latter case all the other segments would have to have 0 length, since the total of all segments equals n.) Represent mathematically all the possible lengths of the first segment by the expression

$$x_1^0 + x_1^1 + x_1^2 + \dots + x_1^n \qquad (1)$$

in which the *exponent* of x_1 indicates the number of units in the segment. Similarly the second segment's possible values can be represented by the same form of series, and the third segment, etc., up to the mth segment. We write them all down, as though they were to be multiplied together, as follows,

$$(x_1^0 + x_1^1 + x_1^2 + \dots + x_1^n)$$
$$(x_2^0 + x_2^1 + x_2^2 + \dots + x_2^n)\dots$$
$$(x_m^0 + x_m^1 + x_m^2 + \dots x_m^n). \qquad (2)$$

Next imagine all of the multiplications performed. After dropping the subscripts and collecting, the terms will range in degree all the way from Ax^0 to Wx^{mn}. Somewhere there will be a term of the form Hx^n, and it will consist of selections of x's one from each series, such that the sum of their exponents always equals n. In fact all possible combinations of such selections will have been discovered in multiplying out the above product of series, and the

* The technique used here is known as that of generating functions. It was used in the solution of this problem for the special case of $c = 0$, by E. C. Molina of the American Telephone and Telegraph Co. in an unpublished memorandum of September 1, 1921.

number of such cases with exponents totaling n will be the *coefficient* of this x^n term. But this is also the number of ways in Fig. 1 that m segments could have been given values from 0 to n, such that their total was always equal to n. Hence the coefficient of x^n in the expansion of $(x^0 + x^1 + x^2 \ldots + x^n)^m$ will be the number of ways in which a line n units long can be divided into m segments.

The Mathematical Problem

The coefficient of x^n in $(x^0 + x^1 + x^2 + \ldots + x^n)^m$ will be the same as in $(x^0 + x^1 + x^2 + \ldots)^m$ in which the terms within the parenthesis do not end with x^n since the x^{n+1} and higher terms could contribute no cases to the final Hx^n term we are seeking. We then note that $(x^0 + x^1 + x^2 + \ldots)^m = (1 - x)^{-m}$. Expanding this binomial according to the rule for negative exponents, we have

$$(1 - x)^{-m} = 1 + mx + \frac{m(m+1)}{2!}x^2 + \ldots + \frac{m(m+1)\ldots(m+n-1)}{n!}x^n + \ldots. \quad (3)$$

Here the coefficient of x^n is

$$\frac{m(m+1)\ldots(m+n-1)}{n!} = \binom{m+n-1}{m-1} \quad (4)$$

where the lefthand side of Eq. (4) denotes the number of combinations of $m + n - 1$ things taken $m - 1$ at a time and the righthand side is a convenient notation meaning the same thing. This then is the total number of ways of dividing the line in Fig. 1 into m segments, with no restriction on the length of any one segment, the only requirement being that the lengths of the m segments add up to n.

Suppose we should now like to determine the probability that none of the m segments above is s units or longer. If we can determine how many "favorable" ways the line of Fig. 1 can be divided into m parts no one of which is longer than $s - 1$ units, the ratio of favorable to total ways will then produce the desired probability, $P_{m \cdot 0}$, that of m segments none will equal or exceed s in length.

To determine the number of favorable ways we proceed exactly as before representing each segment with a mathematical series, but now permitting no single series to go beyond the x^{s-1} term. The m series when multiplied together are then

$$(x^0 + x^1 + x^2 + \ldots + x^{s-1})^m, \quad (5)$$

and we have the problem again of finding the coefficient of x^n, the number of ways of dividing the line n units long into m segments no one of which is s or more units in length.

Expression (5) may be rewritten as

$$(1 - x^s)^m/(1 - x)^m = (1 - x^s)^m(1 - x)^{-m} \quad (6)$$

Expanding each of the latter two factors, gives

$$\left[1 - mx^s + \frac{m(m-1)}{2!}x^{2s} + \ldots + (-1)^k\frac{m(m-1)\ldots(m-k+1)}{k!}x^{ks} + \ldots\right] \times \left[1 + mx + \frac{m(m+1)}{2!}x^2 + \ldots + \frac{m(m+1)\ldots(m+n-1)}{n!}x^n + \ldots\right] \quad (7)$$

It may now be seen that the coefficient of x^n in (7), that is, the number of favorable ways, is

$$\frac{(m+n-1)!}{(m-1)!n!} - m\frac{(m+n-s-1)!}{(m-1)!\,(n-s)!} + \frac{m!}{(m-2)!2!}\frac{(m+n-2s-1)!}{(m-1)!(n-2s)!} + \ldots + (-1)^k\frac{m!}{(m-k)!k!}\frac{(m+n-ks-1)!}{(m-1)!(n-ks)!} + \ldots \quad (8)$$

$$= \frac{(m+n-1)!}{(m-1)!n!} \times \left\{1 - m\frac{(m+n-s-1)!}{(n-s)!}\frac{n!}{(m+n-1)!} + \frac{m!}{(m-2)!2!}\frac{(m+n-2s-1)!}{(n-2s)!}\frac{n!}{(m+n-1)!} + \ldots + \right.$$

$$(-1)^k \frac{m!(m+n-ks-1)!}{(m-k)!k!(n-ks)!(m+n-1)!} \frac{n!}{} + \ldots \Big\} \quad (9)$$

$$= \frac{(m+n-1)!}{(m-1)!n!} \Big\{ 1 + \sum_{t=1} (-1)^t \binom{m}{t} \times \frac{(m+n-ts-1)!n!}{(n-ts)!(m+n-1)!} \Big\} \quad (10)$$

Then the probability sought is

$$P_{m,0} = \frac{\text{Favorable Ways}}{\text{Total Ways}} = \frac{\text{Equation (10)}}{\text{Equation (4)}} = 1 + \sum_{t=1} (-1)^t \binom{m}{t} \times \frac{(m+n-ts-1)!n!}{(n-ts)!(m+n-1)!} \quad (11)$$

Now if we imagine the line in Fig. 1 to be made up of such a very large number of units that n approaches infinity, then s likewise will approach infinity. We retain however the desired conditions by setting $s/n = r$ and requiring now that no one of the m segments should exceed the specified proportion r of the total length. With n and s approaching ∞ and $s/n = r$, the last fraction in Eq. (11), $(m + n - ts - 1)!n!/(n - ts)!(m + n - 1)!$, can be evaluated by Stirling's Theorem for factorials, and is found to be $(1 - tr)^{m-1}$. Equation (11) can be rewritten more simply as

$$P_{m,0} = 1 + \sum_{t=1} (-1)^t \binom{m}{t} (1 - tr)^{m-1} = 1 - \binom{m}{1}(1-r)^{m-1} + \binom{m}{2}(1-2r)^{m-1} - \binom{m}{3}(1-3r)^{m-1} + \ldots \quad (12)$$

in which the series extends for all values of t as long as $t < \frac{1}{r} < m$.

By a similar but slightly more involved procedure we can find the probability, $P_{m,c}$, that exactly $c = 1,2,3,\ldots$ segments of the picture interval I will have length ratios greater than r, while the remaining $m - c$ are all shorter than r. Thus

$$P_{m,c} = \binom{m}{c} \sum_{t=c} (-1)^{t-c} \binom{m-c}{t-c} (1 - tr)^{m-1} \quad (13)$$

in which $(-1)^{t-c}$ insures the terms of the series alternate in sign.

The probability that not more than c segments exceed a length ratio of r, is found from

$$P_{,m \not> c} = \sum_{j=1}^{c} P_{m,j} = 1 - \sum_{t=c} (-1)^h \binom{t}{t-c} \binom{m}{t+1} [1-(t+1)r]^{m-1} = 1 - \binom{c}{0}\binom{m}{c+1}[1-(c+1)r]^{m-1} + \binom{c+1}{1}\binom{m}{c+2}[1-(c+2)r]^{m-1} - \binom{c+2}{2}\binom{m}{c+3}[1-(c+3)r]^{m-1} + \ldots \quad (14)$$

Placing an added restriction on the problem, we may by a similar analysis write the probability $P'_{m,c}$ that c segments will exceed a length ratio r, but will not however exceed $2r$. Equation (13) then becomes

$$P'_{m,c} = \binom{m}{c} \sum_{t=c} (-1)^{t-c} \binom{m}{t-c} (1 - tr)^{m-1} \quad (15)$$

Correspondingly, when *not more* than c segments are to be permitted to exceed a length ratio r (and none a length ratio of $2r$), we have from Eq. (15)

$$P'_{m,\not> c} = \sum_{j=0}^{c} P'_{m,j} = 1 + \sum_{t=1} (-1)^t \Big[\binom{m}{0}\binom{m}{t} - \binom{m}{1}\binom{m}{t-1} + \ldots + (-1)^c \binom{m}{c}\binom{m}{t-c} \Big] (1 - tr)^{m-1} \quad (16)$$

Charts and Tables

The curves of Fig. 2 have been calculated from Eq. (12) for $P_{m,0}$, the prob-

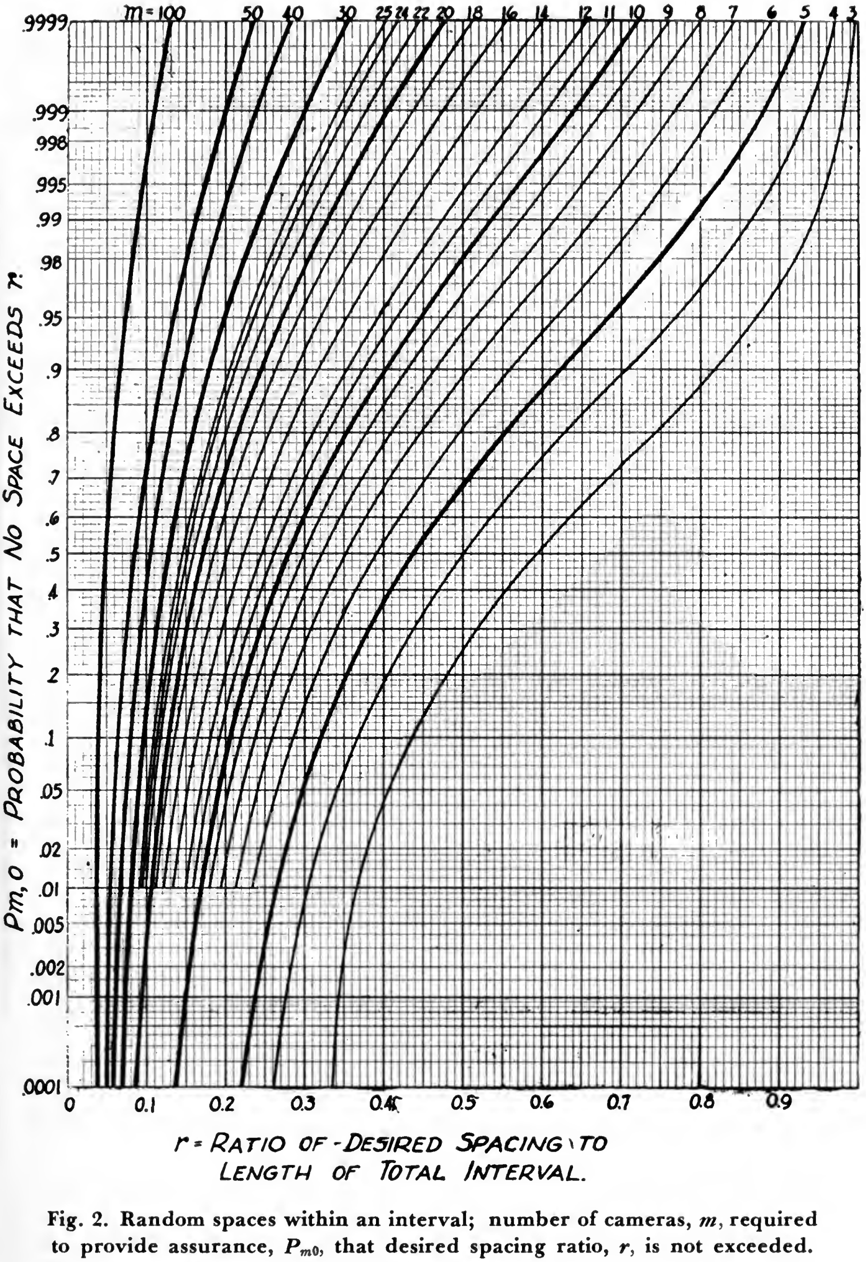


Fig. 2. Random spaces within an interval; number of cameras, m, required to provide assurance, P_{m0}, that desired spacing ratio, r, is not exceeded.

ability that no one of the m segments will exceed the specified proportion r of the total interval. Figure 3 gives the probability, $P'_{m} \not> 1$, that no more than one of the segments exceeds the proportionate length r, and if so is less than $2r$, and is calculated from $P'_{m} \not> 1 = P_{m,0} + P'_{m,1}$.

From the curves of Fig. 2, Table I is constructed for ready reference. It gives the numbers of segments into which a line must be divided to obtain various assurances that all the segments will be shorter than any desired proportion of the line's total length.

Table I. Number of Segments (Cameras) Required to Yield an Assurance $P_{m,0}$ That No Segment (Picture Space) Exceeds a Proportion r of the Entire Line (a Selected Frame Interval).

$P_{m,0}$	$r = 0.2$	$r = 0.3$	$r = 0.4$	$r = 0.5$
0.90	26	16	10	7
0.95	30	18	12	9
0.99	39	23	16	11
0.999	50	29	20	15

Interpretation in Terms of the Camera Problem

If the motion-picture cameras employed jointly in taking photographs of a rapid phenomenon can be assumed to be operating substantially in random phase with one another, then the probability relationships derived above can be directly applied to any phenomenon of special interest which occurs so quickly as to fall within the picture interval time of one camera. This of course will not always be the case since one's interest may commonly extend over several, or many, framing intervals.

If by some feature of synchronous motor design, or other means, one could ensure only a small difference in the frame speeds of the several cameras employed (say less than 1%), it would by possible to extend a statement regarding one I interval to cover a period of such intervals, since successive intervals would repeat almost identical picture spacings. It is more likely, however, that the framing speeds of a group of cameras will vary quite widely, for example up to ±10% from a nominal value. Then with a limited number of cameras one I interval can hardly be considered as looking like its predecessor or successor, either actually or statistically, and a strong statement as to the probability of exceeding an allowable picture spacing *anywhere* in a short strip of several frames would be quite difficult to set down. However, for a period of only 2 or 3 frames, using cameras with no more than a few percent speed variation, it would seem likely that the picture configuration would not have changed so much but that one could usually apply usefully the single interval probability analysis; that is $P_{m,c}$ is approximately the probability that exactly c intervals in each frame exceed the permitted spacing.

Example 1. If 10 high-speed cameras, each having a picture rate of 5000/sec, are used in parallel to photograph a projectile striking a barrier, what is the probability that during the 0.2 msec following impact there will be no interval between pictures longer than $i = 0.0001$ sec? Here the picture interval for a single camera is $I = 0.0002$ sec. The ratio r of the permissible interval i to the whole interval I is $r = 0.5$. Entering the chart of Fig. 2, with an abscissa of $r = 0.5$, and reading up to the $m = 10$ curve, we find a point opposite $P_{m,0} = 0.98$. Thus we have an assurance of 98 chances in 100 that there will be no picture spacing among all those of interest which exceeds 0.0001 sec.

Example 2. Suppose in Example 1 only 5 cameras instead of 10 had been available. How much would the assurance have been lowered that the longest picture space would not exceed 0.0001 sec? Again consulting Fig. 2, we see the probability is reduced from 0.98 to 0.69,

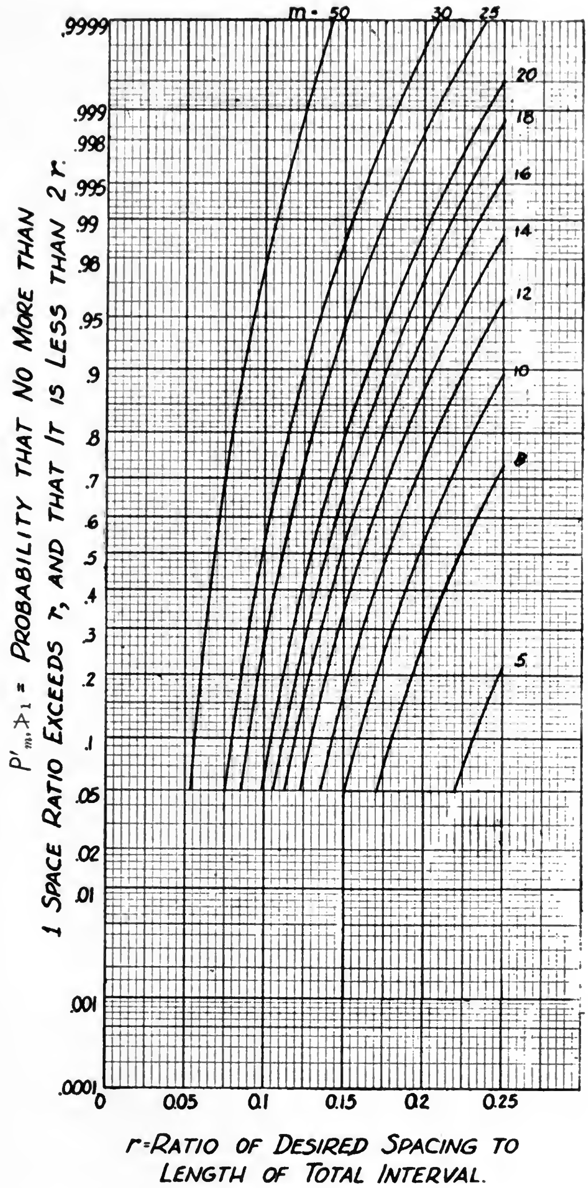


Fig. 3. Random spaces within an interval; number of cameras, *m*, required to provide assurance, $P'_{m,\ngtr 1}$, that desired spacing ratio, *r*, is not exceeded by more than one case and that that case is less than $2r$.

which might not now be an acceptable assurance if it were highly important that *no* picture spacing exceed 0.0001 sec.

Example 3. In a certain type of explosion lasting about 0.01 sec, pictures are desired no further than 0.001 sec apart. Twenty cameras are at hand operating at 200 frames/sec. Will they be adequate to the requirements if operated in parallel with random synchronization? Here $r = 0.001/(1/200) = 0.2$, and from Fig. 2 we read that the probability is only 0.72 that all picture spaces will be less than the desired ratio. This would likely not give sufficient confidence of the scheme's satisfactoriness. We should perhaps then choose the minimum probability which would give us a feeling of confidence, say $P = 0.90$. With 20 cameras and this new assurance we find on Fig. 2 the corresponding r to be 0.24, which is only a little larger than the 0.20 originally specified, and might very well be a tolerated spacing since this is an *upper limit* (not exceeded with probability $P = 0.90$) to the largest picture space at the moment of explosion. Or, alternatively, permitting the interval ratio to increase to $r = 0.3$, would raise to $P = 0.977$ the assurance that none of the picture spaces exceeds this amount.

Example 4. Another alternative to the solutions of Example 3 is to retain $r = 0.2$ as originally proposed, but now permit one space ratio to be as large as $2r$, that is $r_1 = 0.4$, all other space ratios remaining less than 0.2. (This largest space ratio is not required to exceed 0.2, it merely may exceed it.) When the conditions are thus slightly relaxed, the probability of meeting them can be read from Fig. 3. In the present example, the assurance is 0.987, which is almost identical with that obtained when all ratios were allowed to go as high as $r = 0.3$. This information combined with the original assurance that 72% of the time all picture spaces of interest would be less than 0.001 sec ($r = 0.2$), might persuade us that the employment of 20 cameras here would be satisfactory.

If the event of interest covers a long strip of film, the analysis above can still be useful. With a number of cameras running at different speeds we may visualize that before very many hundreds of frames have been run off the aggregate of the I-intervals will have produced a variety of arrangements and lengths of picture spacings not unlike those comprising the "Total Cases" in the mathematical analysis above. Then we may interpret $P_{m,c}$ as not only the probability of a selected random I-interval containing c picture spacings greater than r, but also that of all the large number of I-intervals we should expect a proportion $P_{m,c}$ to have just c spacings greater than r. Furthermore, if $P_{m,0}$ is chosen close to unity (the usual case) the occurrence of more than one space exceeding r in the same I-interval will be rare; in which circumstance we may expect closely the proportion $\frac{1}{m}(1 - P_{m,0})$ of all the picture spaces in the film to exceed the length r, and the proportion

$$1 - \frac{1}{m}(1 - P_{m,0}) \qquad (17)$$

to be smaller than r.

Example 5. In photographing a rapid machine operation, how many cameras in random synchronization must be provided so that 99.9% of all picture spacings can be expected to be shorter than 0.2 of the single-camera frame interval? By trial in Eq. (17) it is found that $n = 31$ cameras yield $E = 0.999$. Since the value of $P_{m,0}$ involved here is close to unity (0.965), it may be assumed that most of the remaining probability is comprised by $P_{m,1}$ and the approximation of Eq. (17) will be satisfactory.

Finally there is the important case* in which an event of extremely short duration may conceivably fall in so long a picture space that satisfactory analysis of its character cannot be made. We here require the probability that a random point in time will fall in a picture interval greater than r. The solution involves weighing the probability of occurrence of intervals having 0, 1, 2 ... picture spaces longer than r by the probability that when such spaces occur, the random point will fall in one or another of these "long" spaces. The solution is readily obtained using an extension of the previous analysis.

The average length of a picture space of the "too long" variety, when it occurs, is required. The ways in which with m cameras a *single* space of length $z = s + k$ or longer can occur is given by the coefficient of x^n in the array,

$$\binom{m}{1}(1 + x + \ldots + x^{s-1})^{m-1} \times (x^{s+k} + x^{s+k+1} + \ldots). \quad (18)$$

Determining the ratio of favorable ways to total ways, and as before letting n, s and z approach infinity, with $s/n = r$, $z/n = j_1$, results in

$$P\,(\text{single space} \geqq j_1) = m\sum_{t=1}(-1)^{t-1} \times \binom{m-1}{t-1}[1 - j_1 - (t-1)r]^{m-1} \quad (19)$$

where the upper limit of t is the integral part of $(1 - j_1)/r + 1$. Then the relative frequency of occurrence of one "too long" space of length j_1 is

$$f(j_1)dj_1 = \frac{-dP(\geqq j_1)}{dj_1} = m(m-1) \times \sum_{t=1}(-1)^{t-1}\binom{m-1}{t-1} \times [1 - j_1 - (t-1)r]^{m-2} \quad (20)$$

* Called to the authors' attention by C. D. Miller of Battelle Memorial Institute.

And finally the average value of j_1 is

$$\bar{j}_1 = \frac{\int_r^1 j_1 f(j_1)dj_1}{P_{m,1}} = \frac{1}{P_{m,1}}\sum_{t=1}(-1)^{t-1}\binom{m-1}{t-1} \times [mr(1-tr)^{m-1} + (1-tr)^m] \quad (21)$$

where the upper limit of t is now the integral part of $1/r$.

Similarly expressions for $\bar{j}_2, \bar{j}_3, \ldots \bar{j}_i \ldots$ can be obtained which give the average picture space when 2, 3, ... i, ... spaces exceed the permitted ratio r.* Then the total probability that the point-event will *not* fall in a "too long" space is

$$H = P_{m,0} + P_{m,1}(1 - \bar{j}_1) + P_{m,2}(1 - 2\bar{j}_2) + \ldots \quad (22)$$

In the usual case $P_{m,2}, P_{m,3}\ldots$ will be small, also $\bar{j}_1 > \bar{j}_2 > \bar{j}_3 \ldots$, so that close upper and lower limits on H are, respectively,

$$\left.\begin{aligned} H_U &= P_{m,0} + P_{m,1}(1 - \bar{j}_1) + P_{m,2} + P_{m,3} + \ldots \\ H_L &= P_{m,0} + P_{m,1}(1 - \bar{j}_1) + P_{m,2}(1 - 2\bar{j}_1) + P_{m,3}(1 - 3\bar{j}_1) + \ldots \end{aligned}\right\} \quad (23)$$

Example 6. With varying numbers of cameras, from 20 to 50, operating at 5000 frames/sec, what is the probability that an event of extremely short duration will fall in a picture interval longer than 0.04 msec? Here $I = 0.0002$, $r = 0.00004/0.0002 = 0.2$. Solving for $\bar{j}_1$ in (21) and substituting in the two limit expressions of (23), yields the following values:

* It may be noted through geometrical consideration, that when $(1 - r)/mr$ is small, say less than 0.2, $\bar{j}_i$ is closely approximated by $r + \frac{1 - ir}{m}$.

Table II

m	$P_{m,0}$	$P_{m,1}$	$P_{m,2}$	$P_{m,3}$	j_1	H_U (upper limit to H)	H_L (lower limit to H)
20	0.723316	0.265169	0.011484	0.000031	0.24087	0.9361	0.9306
30	0.953738	0.046102	0.000160	—	0.22672	0.9895	0.9895
40	0.993356	0.006643	0.000002	—	0.22000	0.9985	0.9985
50	0.999108	0.000892	—	—	0.21600	0.9998	0.9998

The limits here are seen to specify very narrowly the desired probability H. In this example, if an assurance of approximately 0.99 is desired that the point should not fall in a space longer than 0.04 msec, 30 cameras need to be provided.

Acknowledgments

The authors wish to acknowledge the mathematical assistance of Mrs. S. P. Mead, and to thank Misses C. A. Lennon and A. G. Loe of Bell Telephone Laboratories for computing the curves of Figs. 2 and 3.

The numerous comments made by the discussions of this paper have added greatly to its interest and value. The authors are particularly indebted to C. D. Miller for his careful reading of the material and his comments on several points which were probably confusing and possibly misleading. We have attempted to clarify the presentation with the hope that the multiple camera method can be employed with but little likelihood of misapplication. Those shortcomings which remain are, of course, the responsibility of the authors.

Discussion

Richard O. Painter, (*General Motors Proving Ground, Milford, Mich., and Chairman of the Session*): At this time we will have any questions from the floor.

Kenneth Shaftan (*J. A. Maurer, Inc.*)*: My comments will constitute a discussion rather than a question. The authors have achieved a partial solution to the problem of complete coverage of various phenomena. Of course, one of the best approaches to the problem is to utilize some aspect of the phenomenon under study which can be recorded in some continuous manner. Then you are no longer worried about sampling rates. A consideration fundamental in a system such as that treated by the authors is the fact one must be able to arrive easily at a timewise correlation between the runs of different cameras. The man-hours being spent on this fundamental problem are tremendous.

The timewise correlation can be achieved directly by various systems of synchronizing cameras. Such a synchronization can be achieved at high frame rates. For example, let us consider the case of a camera wth a rotating prism having two plane surfaces. Two such cameras can be synchronized with the prisms 90 degrees out of phase. With 360 such cameras we could provide synchronization for each half degree of prism rotation, hence, 360 times the framing rate.

One of the most important considerations, though, is that of lashing down time in such a fashion as to establish the interval between frames exceptionally well for the individual camera, as well as this matter of synchronization from run to run, or camera to camera.

Mr. Wilkinson: You would certainly need a time trace of some sort that was appearing simultaneously in all of the camera films so you could lay the pic-

* The transcript of Mr. Shaftan's remarks has been edited by C. D. Miller after Mr. Shaftan's death, to provide this discussion.

tures alongside each other to test what distance camera No. 2, for example, was from camera No. 1.

Mr. Shaftan: That is the big problem.

Mr. Wilkinson: Apparently they have been able to do something along that line. I see Mr. Waddell, who used this technique, nodding his head. How he did it you will have to ask of him.

John E. Voorhees (Battelle Memorial Institute): In the example you cited, using several cameras in the photography of an atomic bomb explosion, what solution was chosen from this computation?

Mr. Wilkinson: The answer to that question cannot be revealed.

Dr. Schardin: You say it can't?

Mr. Wilkinson: I don't believe so.

[Discussions by H. Schardin and by C. D. Miller have been clarified and amplified at the request of the Chairman of the Board of Editors and appear below in the revised forms.]

Comments Solicited by the Chairman of the Board of Editors

Dr. H. Schardin (Laboratoire de Recherches, St. Louis, France): The object of a motion-picture series is to make possible an analysis of the space-time relations of a visible phenomenon after its occurrence. With most photographic equipment, the quality of resolution of space and time are mutually dependent. In other words a higher repetition rate is possible only through a reduction of image size. Here we are considering the question as to how an improvement of timewise resolution can be accomplished without change of the resolution spacewise.

An often-used method, propounded by the authors, is to increase the number of frames per second by the simultaneous use of a number of identical pieces of equipment. With this method, each apparatus photographs the subject on the same scale as if it were used alone. If n similar cameras are used, each with a repetition rate of approximately f_w, the average combined repetition rate may be expressed as nf_w. However, the quality of the timewise resolution is not then simply proportional to nf_w. It is instead proportional to $(g) \times (nf_w)^{3/2}$, where g is the resulting quality factor.* The quality factor g in this case is the ratio of the reciprocal of the repetition rate to the exposure duration of an individual frame.

If n cameras are used side by side, although the average repetition rate increases to nf_w, the average quality factor decreases to $\frac{g}{n}$. Hence, the timewise resolution is proportional to

$$\frac{g}{n}(nf_w)^{3/2} = \sqrt{n} \times gf_w^{3/2}.$$

The timewise resolution, therefore, is only $\sqrt{n}$ times as great as with the use of a single camera.

Conditions become essentially more favorable if, with the increase in number of cameras, the nature of the cameras is changed. The repetition rate is limited, among other things, by the frame height (not by the frame width). To obtain better timewise resolution, cameras can be used with a suitable n-fold reduction of the frame height. Such an arrangement allows an n-fold increase in repetition rate with an unchanged quality factor. In many cases, such an arrangement is simple to realize with prism apparatus.

The entire field is now no longer photographed by each camera. Instead, the individual fields of the cameras border each other. With n cameras the field of each camera corresponds to one nth part of the entire field. Yet the entire field is recorded with unchanged spacewise resolution. The timewise resolution is then proportional to

$$g(nf_w)^{3/2} = n^{3/2} \times gf_w^{3/2},$$

---

* See H. Schardin, *Schweizerische Photorundschau, 14:* p. 294 (1951).

which is better than in the previous case by the factor $\frac{n^{3/2}}{\sqrt{n}} = n.$

If cameras with an n-fold reduction of frame height but unchanged frame width are not available, the possibility can still be investigated of using suitable equipment with which the frame height and frame width are reduced in like degree. For example, 4 16mm cameras or 16 8mm cameras can be used in preference to 4 or 16 35mm cameras. By use of such narrow-film cameras, a timewise resolution is obtained proportional to

$$g(\sqrt{n}f_w)^{3/2} = n^{3/4} \times gf_w^{3/2}.$$

In comparison to n cameras using film of normal width, we then have an advantage in timewise resolution by a factor of $n^{1/4}$, as well as the further advantages of reduced area of film required by a factor of $\sqrt{n}$ and lower cost of the experimental equipment.

We are often not concerned with such material advantages, but only with increasing the accuracy of measurement to allow even the establishment of the existence of an effect that has been sought. It should be pointed out here that a fundamental advantage is offered, with the simultaneous use of a number of cameras, by the principle of subdivision of the field. With use of this principle, it is not of great importance whether the cameras are synchronized or not.

C. D. Miller (*Battelle Memorial Institute*): The authors have contributed a valuable service in providing a mathematical solution to the probability of capturing rapid events by a sampling technique.

As pointed out by Dr. Schardin, an increase in repetition rate with unchanged exposure duration for the individual frame is of considerably less value than a like increase in repetition rate accompanied by a proportional reduction of exposure duration. However, the nuances encountered in the application of this principle are quite remarkable.

The question of the desirability of a small ratio of exposure duration to interval between consecutive frames depends a great deal upon the purpose of the photographs. Ordinarily, if the purpose is to treat the individual frames as stills, and to make measurements of displacements from those stills, there is certainly nothing to be gained by having more exposures per second than the reciprocal of the exposure duration of an individual frame. Ordinarily there is even little to be gained in obtaining more than one-tenth that repetition rate.

On the other hand, if the purpose is to produce a motion picture for viewing on a projection screen, there is an advantage in increasing the number of pictures even beyond the reciprocal of the exposure duration. However, for this purpose, the increased number of pictures can be obtained in the process of reproduction from the original film, rather than by extending the repetition rate of the high-speed camera beyond the reciprocal of the exposure duration.

We took some photographs at NACA of the phenomenon of knock in a spark-ignited piston engine at 200,000 frames/sec, approximately the reciprocal of the exposure duration. However, when these photographs were projected at 16 frames/sec, the detonation wave which travels through the mixture at the time of knock was still too fast to follow readily by eye. So we printed those pictures, dissolving one frame into the next in the printing process, so that over a distance of five frames on the print we gradually changed from the first to the second frame that we had taken with our high-speed camera, over the next five frames we dissolved from the second frame into the third, and so on. By that method, we obtained a slow-motion picture which showed on the projection screen very distinctly a phenomenon that could not be seen when the original photographs were projected, and with no visible decrease in the spacewise resolution. Moreover, this result could not be obtained by simply printing each frame of the original five times on the print. The effect of dissolving one frame into the next was essential. Moreover, this method of slowing down the motion picture by multiplication of frames in the printing process would probably not be successful if the repetition rate of the high-speed camera were substantially less than the reciprocal of the exposure duration.

Essentially, all information obtained from high-speed photographs consists of determination of spatial velocities at various instants of time. A rate determination, of course, consists of a distance divided by a time interval. In such determinations from high-speed photographs, the distance used is proportional to the reciprocal of the repetition rate. The degree of accuracy of the determination of this distance, however, varies inversely with the exposure duration. Hence, as the exposure duration is increased relative to the reciprocal of the repetition rate, the accuracy of the determination of distance, and hence the accuracy of the determination of rate, diminishes.

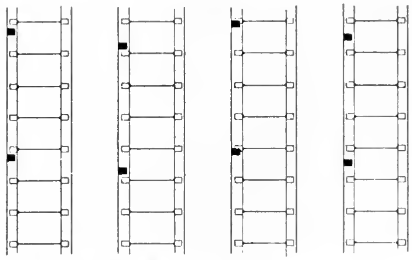
A rate determined upon the basis of the distance moved between the exposure of two successive frames must, of course, be an average rate for the movement between the exposures of those two frames. The rate at any instant between the two exposures may be treated as approximately equal to the average rate throughout the interval between the two exposures. Better, a curve may be constructed from average rates determined for the intervals between a large number of consecutive frames, and the rate for any instant of time may be read from the curve so constructed.

Even the second procedure is only approximate. Hence the desire to obtain more accurate determination of rates for several chronological points between the exposures of successive frames, by the exposure of additional frames throughout the interval. However, as we increase the number of exposures without decreasing the exposure duration, we encounter this problem of diminishing accuracy. Unfortunately, as we reach the value of repetition rate equal to the reciprocal of the exposure duration, the accuracy of the rate determination diminishes to about the same value as would be determined by a curve constructed from photographs taken at a lower repetition rate.

Problems exist, however, for which the foregoing reasoning does not apply, even when the photographs are used as stills for measurements. An example would be a hypothetical event in which an object becomes intensely luminous within an interval of perhaps one microsecond or less. In such a case, it might be desired to determine the exact time of development of luminosity. The luminosity might be assumed to be so great as to produce a dense exposure on the photosensitive film within one microsecond. Under these conditions, assuming an exposure duration of one millisecond provided by an individual camera, and assuming an infinitely quick cutoff of the exposure in each camera, Camera *A* might photograph the luminosity during the last microsecond of its one-millisecond exposure, whereas Camera *B*, phased one microsecond later than Camera *A*, would miss the development of the luminosity entirely. In such a case, great value might result from an increase in repetition rate far beyond the reciprocal of the exposure duration, if means were provided for a sufficiently accurate determination of the relative phasing of the cameras. Also, in this case, Dr. Schardin's quality factor would not apply in any simple manner.

John H. Waddell (*Wollensak Optical Co.*): I would like to present the two primary reasons for inviting the authors to give this classic paper on the application of random sampling to high-speed camera operation.

(1) Field Operation. Oftentimes it is necessary to round up or to use equipment which is readily available, and to



Discussion Fig. 1. Timing pips in four films; time separation, 1 msec. Order in which films would be read or printed: (1) C, (2) A, (3) D and (4) B.

get the best results for a minimum number of dollars. The questions one asks first are: How portable is the equipment, and is it easy to set up and to use?

It is conceivable to set up a synchro-selsyn system for camera operation which would cost a million or two million dollars, and would require two or three years to develop and another six months or a year to train a crew to operate the system. Furthermore, such a system has a complex operating mechanism which requires top-flight engineers to set it up and to maintain it.

It is also possible to design and build single cameras to perform such a task—but where is a camera system which can possibly photograph up to *x* number of camera times 4000, 16mm pictures, or 8000, 8mm pictures times the fraction of a second that it takes the 100-ft lengths of film to be taken with a synchronizing time signal of 0.001 in. on all films? The high repetitive rate cameras are either bulky (may weigh up to 4 tons), do not have the desired time cycle, or their resolution is not as much as desired.

Furthermore, it is often desirable to design completely a complete operating photographic system in as little as two weeks, and not two years.

(2) Interpretation of Results. The films obtained can be either projected or read frame by frame.

Typical timing marks with respect to frame positions for four cameras are shown in Discussion Fig. 1.

In frame-by-frame analysis, the timing can be considered linear between any two timing marks, since the change in slope on acceleration or in steady state is negligible and below the limits of experimental error. With the same signal from the master oscillator being placed on all the films, and with zero time starting after the cameras are moving, the counting is a comparatively easy task.

As far as the motion-picture record goes, there is an accepted practice in printing in which a single frame can be printed in any multiple desired (as the 24 frames of the Schardin picture which were printed about 5 times each to get a long record), or the frames from different negatives can be printed on a single film by skip printing the positive. In the optical printer, there must be some means available for checking the negative registration.

I believe this paper is of fundamental and classical importance, and is an unbiased, extremely valuable contribution to the science of high-speed photography.

High-Speed Photography in the Chemical Industry

By W. O. S. JOHNSON

The du Pont Company's Mechanical Development Laboratory has made use of high-speed photographic techniques in the evaluation of chemical, metallurgical and mechanical processes. To cover the wide range of subjects encountered, some development work on cameras, lights and associated equipment has been necessary. This work is described herein.

THE Mechanical Development Laboratory of the du Pont Company's Engineering Department purchased its first high-speed photographic equipment, a Western Electric Fastax 16mm camera, in 1946 after a series of successful pictures had been taken for it by an outside consultant firm. These pictures covered the early stages of the development of a new autoloading shotgun, in cooperation with the Remington Arms Co., and showed clearly the accomplishments possible in the field of high-speed motion analysis. Following these early pictures, every design change on the new gun was assessed by means of high-speed photography. The action of each latch, spring and lever, and the effect of high- and low-velocity shells on the mechanism were the subject of numerous pictures.

Presented on October 9, 1952, at the Society's Convention at Washington, D.C., by W. O. S. Johnson, E. I. du Pont de Nemours & Co., Inc., Mechanical Development Laboratory, 101 Beech St., Wilmington, Del.
(This paper was received Sept. 21, 1953.)

In connection with the development of a safety device for a black powder wrapping machine, it was necessary to determine the flame-propagation speed of the particular type of powder being handled and then to develop a suitable guillotine-type door which would seal off the entry and exit ports to the room containing the machine. In this operation, unwrapped black powder pellets are fed to the machine in a continuous stream on a belt conveyor. After tests were run to determine the flame-front velocity of the stream of powder, a photocell-triggered gate was developed and tested. High-speed pictures of this gate revealed all the critical factors:

(1) the triggering electronic circuit performed satisfactorily;

(2) the water spray preceded the blade in its downward travel;

(3) the blade closed within the desired interval (actual stroke duration less than 10 msec);

(4) the deceleration pads operated as planned; and

(5) the flame was completely stopped at the barrier even though a solid powder

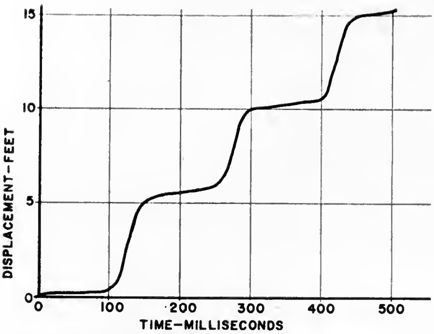


Fig. 1. Curve showing flame front travel in train of unwrapped black powder pellets.

line had existed through the opening and the condition of the powder dust typical of the operation was simulated as nearly as possible.

A time-displacement curve of the powder flame front is shown in Fig. 1.

Next, the assistance of high-speed photography was requested in connection with one of the Company's textile fiber packaging operations. To obtain the type of information needed, it was necessary to develop some method of frame-by-frame analysis from which time-displacement curves could be plotted for the elements under investigation. A Bell & Howell Filmosound projector was purchased and fitted with suitable handcrank and frame counter. A heat-reducing filter of sufficient cooling capacity permitted the examination of any single frame for an unlimited period. A projector so equipped can now be purchased as a standard item. This unit proved invaluable in the textile studies, all measurements being made directly from the projected images. A vertical drawing board equipped with a drafting machine was used as a projection screen because of the large number of measurements required. It was found that this arrangement facilitated the measurement of angular rotation as well as linear dimensions, the straight edge being laid tangent to a line on the image and the angle read directly and accurately, regardless of change in position of the rotating member in the field from frame to frame.

One problem which became evident as the use of the high-speed camera was extended, particularly in the textile field and in the study of sprayed materials, was the need for improved time resolution. The Fastax camera as manufactured has an exposure ratio of 1 to 3; that is, at 5,000 frames/sec the exposure duration is 1/15,000 sec, or 66 μsec. In photographing filament action in many yarn-handling operations, calculations showed transverse filament velocity in terms of filament diameter to be high enough so that blurring of the image of the filaments would occur during the 66-μsec exposure. Test runs corroborated these conclusions. Since the rear opening in the camera's aperture box (the stationary box around the rotating prism) serves as the optical equivalent of a focal-plane shutter, it appeared that by varying the vertical height of the opening, the exposure duration could be adjusted independent of the frame rate. Three additional aperture boxes were fabricated, one having a rear aperture one half the normal height; one, one-quarter the normal height; and one having an opening 0.010 in. wide. Using these, exposure durations of 33, 17, and 4 μsec, respectively, were realized at 5,000 frames/sec with some loss in frame height. In order to maintain full frame height, it was necessary to widen the front opening of each aperture box slightly.

A marked reduction in motion-produced blurring was accomplished (Fig. 2); however, the time distortion common to all focal-plane shutter cameras was noted. Of course, a proportional increase in light intensity was necessary.

In order to effect the split-second synchronization of light, camera and

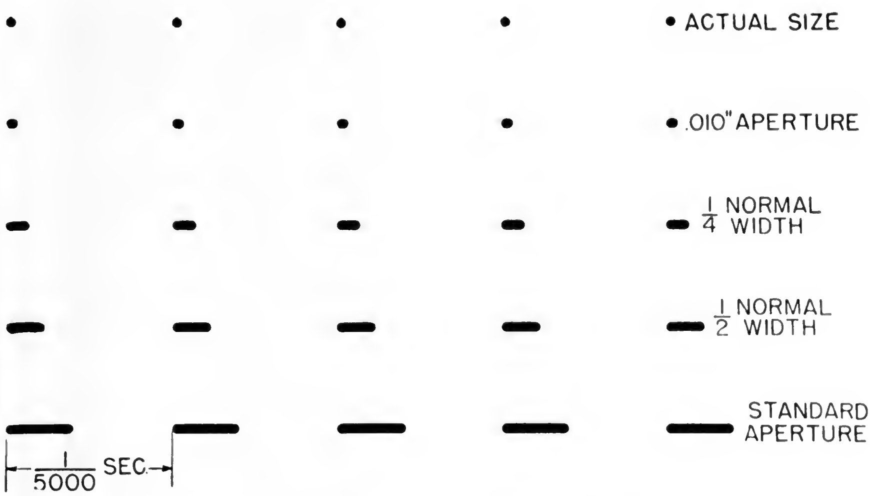


Fig. 2. Appearance of small sphere traveling at 100,000 diameters/sec with various apertures — several consecutive frames superimposed.

subject so often necessary to this work, an overall sequence controller, developed by the Remington Arms Co. for its own use, was adapted with minor modifications. This device controls the operation of the lights, the camera, and single or multiple operation of the event wherever this can be accomplished electrically.

In order to take advantage of the improvements recently incorporated into the Fastax camera, namely the high-resolution prism and the bright-field viewfinder a new 16mm Fastax was purchased. The prism of the original Fastax has been removed in order to provide a high-speed streak and oscillographic camera, which, with the aforementioned aperture boxes, is capable of a time resolution of 2 to 4 μsec. In the study of impacts, for example, it can provide more complete information than any standard frame-type camera since a normal camera sees the object being viewed for but a fraction of the total time, while a streak camera views the object continuously during the taking cycle. Figure 3 is the streak image of a punch as it is struck by a dropping hammer.

An Edgerton high-speed stroboscope was purchased to provide microsecond time resolution without the intense heat produced by the incandescent sources normally used. Many of the operations about which we are most concerned are strongly affected by ambient temperature. The presence of a hot body in close proximity to the operation is often required to provide sufficient light and in several instances has caused a complete breakdown of the process being investigated. This has been particularly evident in research on the mechanism of spinning of synthetic fibers.

In connection with this same research, lens equipment was needed which would provide greater flexibility than those normally supplied with the Fastax camera. We had already obtained the standard complement of lenses including the 25-, 35-, 50- and 104-mm lenses and had built lens extension barrels to permit focusing these lenses at shorter distances than those for which they were normally rated. Due to the unique

Fig. 3. Streak image of punch displacement.

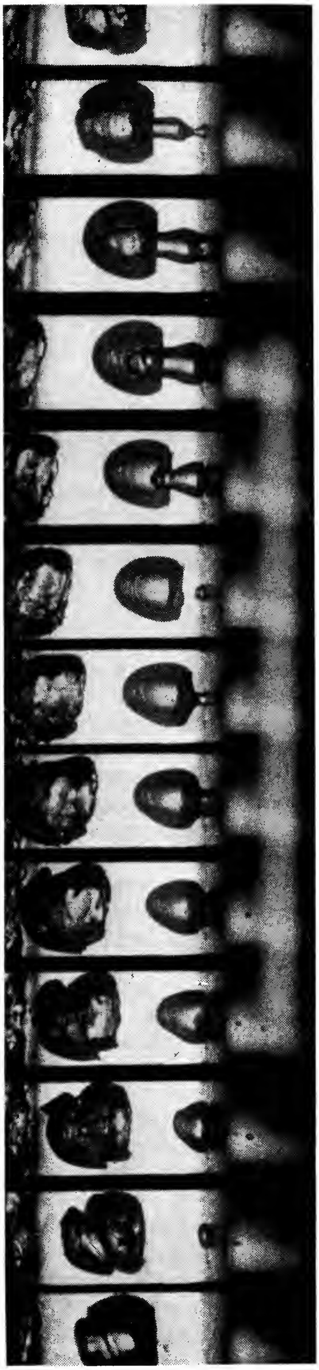


Fig. 4. Sequential stroboscopic pictures of bubble formation in water.

construction of the bayonet lens mount, however, a dead spot existed for each lens since the minimum thickness of the adapters was 5/16 in. This was considerably greater than the total focusing excursion of any of the above lenses. In order to overcome this difficulty, we obtained 48-mm and 72-mm Micro-Tessar lenses and fabricated slip-tube adapters by means of which the lenses could be focused at any film-to-subject distance. These lenses have been used with marked success in microscopic high-speed photographs of individual filaments at magnification ratios up to 5 to 1, field width being less than 1/10 in. The lenses have also been used successfully in macrophotography.

A Sept 35mm camera was purchased and altered to provide a continuously moving film camera which could be used for streak or oscillographic photography. In addition, it has been used in many instances with the Strobotac-Strobolux combination for taking motion pictures of action so slow that the use of regular high-speed equipment was thought to be unnecessary. In this connection, it was found that two or more Stroboluxes may be triggered by a single Strobotac and that by using this arrangement satisfactory pictures of many subjects may be taken. Figure 4 is an example of the use of this technique in studying bubble formation. The operation of bubbling vapors through liquids as a method of accomplishing transfer of either liquid or gas components is a basic operation in many chemical processes. The purpose of the study was to obtain data relative to the effect of bubble rate, gas density and viscosity, liquid density and viscosity, surface tension, hole size, etc. Simultaneous high-speed pictures and dynamic pressure records were taken in many cases.

In addition to the necessarily abbreviated examples presented here of applications of high-speed photography at the du Pont Company's Mechanical Development Laboratory, the technique has been used in the investigation of almost every phase of textile manufacture, from the spinning of a single filament to the sewing of finished fabrics; in the study of paint spraying; in metallurgical studies; and in the investigation of fundamental chemical processes. It has also been used to study the effect of explosions.

High-speed photography has proved to be a valuable research tool; however, our many investigations have shown that there is an enormous field which present equipment does not cover. We are looking forward to the time when picture rates many times in excess of what is now possible will be commonplace.

Full-Frame 35mm Fastax Camera

By JOHN H. WADDELL

A full-frame 35mm rotating-prism type camera is described and its features discussed. The camera has a 500-ft capacity and a picture-taking rate of from 100 to 2500 frames/sec.

Historically, five major 35mm full frame high-speed motion picture cameras have been designed. Jenkins designed one employing a rotating-lens system, later Zeiss and then Wyckoff and Partsch designed a camera using the same principle. Edgerton built one synchronized with flashing high-voltage gas-discharge tubes. Chesterman and Myers designed one using a rotating prism. And there have been several other single cameras, built for specific purposes, some of which used rotating mirrors.

Rotating-Lens Cameras: Herbert Grier, of Edgerton, Germeshausen and Grier, stipulated that measurements from high-speed camera films be accurate to $\frac{1}{10}$ of 1%. It is almost impossible to find 20 or more matched lenses for a rotating-lens camera whose focal length can be maintained to give films within the $\frac{1}{10}$ of 1% requirement, under varying conditions of temperature.

Rotating-Mirror Cameras: These are potentially better but the film drive is rather complex. The optical performance of mirrors is an attractive argument in their favor.

Cameras Using Synchronized High-Voltage Flashtubes: In a camera with no shutter, the flashtube must fire very fast, for reasonably high picture-taking rates. The resolving power desired in cameras today must be better than 50 lines/mm, or the individual line would be 0.01 mm or 0.0004 in. To assure good image quality with a moving film, this film should not move more than 0.0002 in. during exposure. The study of the effect of film velocity versus time of exposure to obtain this quality is:

Time of flash (μsec)	Velocity of film to get 0.0002-in. smear (ips)
1	200
10	20
100	2
1000	0.02

It is to be noted that the high-voltage lamps, when used in conjunction with

Presented on May 1, 1953, at the Society's Convention at Los Angeles, by John H. Waddell, Industrial and Technical Photographic Div., Wollensak Optical Co., Rochester 21, N.Y. This paper was scheduled in the International Symposium on High-Speed Photography held at Washington, October 1952.
(This paper was received October 8, 1953.)

image-compensating type cameras, produce images of the highest possible resolution.

Rotating-prism cameras have been manufactured and used extensively in the 8mm, double-width 8mm, 16mm, and half-frame height 35mm frame sizes. They all have one deficiency, and that is that no satisfactory enlargements can be made on full-frame 35mm film for large-screen projection. On a 16mm film which had 50-lines/min resolution, a 35mm enlargement from the 16mm film has only 20 lines/mm, which does not give good results when projected when compared with films taken on an intermittent camera.

The film capacity of the commercially available cameras was too small, also. Longer runs were desired.

Realizing the need for a 35mm large capacity high-speed camera, the Government of the U.S.S.R. requested the Western Electric Company to design and build such a camera in 1945.

In an earlier paper,* certain suggested improvements of design were discussed. The first of these was prism design, and second, the design of the sprocket.

The full-frame 35mm Fastax now being introduced has the experience of eighteen years of rotating-prism cameras behind it.

The design features and specifications of the new camera are as follows:

Camera Housing: To reduce weight, a magnesium-aluminum casting will be used. It will be heavy enough to withstant high-blast pressures. Parts will be mounted to withstand at least 20 "g" acceleration. The camera housing will enclose the drive mechanism and lens mount, and will be fitted with standard motion-picture threads for mounting on standard motion-picture tripods.

* John H. Waddell, "Design of rotating prisms for cameras," *Jour. SMPE, 53:* 496–501, Nov. 1949 (also in *High-Speed Photography*, vol. 2).

Sprocket: A sprocket of approximately 6-in. diameter is employed. The curvature of this sprocket face very nearly matches the change in back focus created by the oblique rays as they pass through the prism. Since 35mm negative and color stock in the United States is on slow-burning base, the sprocket is designed to take ASA standard negative perforations. A 180° wrap is used as has been the case on previous Fastax cameras. The sprocket is light in weight and is black to prevent halation and reflections from the inside of the sprocket through the viewing holes when an intensely bright self-incandescent subject is photographed.

Film Capacity: 500-ft, special daylight-loading spools have been designed to ensure maximum acceleration and to permit better balancing of the shifting load. The jump at the beginning and the end of the films is minimized. These spools are inclosed in detachable magazines. Each magazine comes supplied with a motor for the take-up. The film is used on spools so as to keep it in place under conditions of vibration and when high centrifugal force is present.

Prism and Housing: The prism is made from Eastman Kodak 450 glass and is four-sided. The housing is very much heavier than on any previous Fastax cameras. It, too, is designed to provide better chopping action of the image. The prism housing is supported by an outboard bearing to make the pictures more steady. The half-frame 35mm-Fastax employs the same method, and that camera has been noted for its steadiness. There is no provision for removing the prism for oscilloscopic purposes, for it has been found that, with the very tight tolerances of fits and adjustment of gears, jumping pictures result from removing the prism housing.

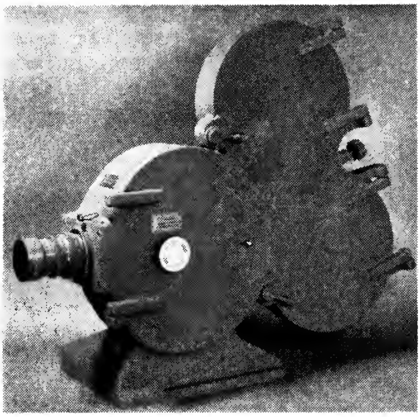


Fig. 1. Front view of the full-frame 35mm Fastax Camera.

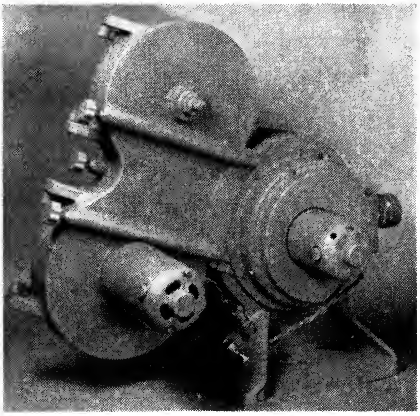


Fig. 2. Rear view, showing adjustable torque feed spindle and motor.

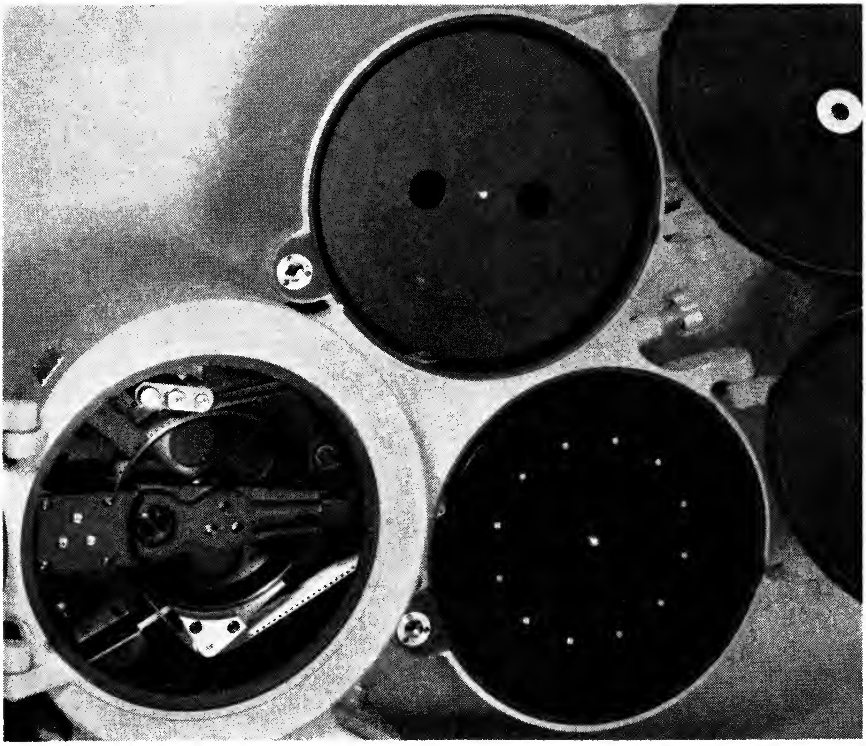


Fig. 3. Interior of camera.

Motors: Universal a-c/d-c type whose speed is dependent on supplied voltage. For isolated field use, storage or hot-shot batteries will operate the camera. Standard a-c (50- or 60-cycle) can be used in the laboratory.

Prism Drive: Simple gear train with ultra-precision gears. The ratio of the driving and pinion gears is one to six.

Lenses: A 4-in. *f*/2.3 lens will be standard on the camera. As has been pointed out, higher overall resolution is obtained with longer focal length lenses. The light is traveling in a more parallel beam. Other lenses available will be:

1-in. *f*/2.3*
35mm *f*/2.3*
2-in. *f*/2.3*
3-in. *f*/2.3
6-in. *f*/2.7
10-in. *f*/4.5
24-in. *f*/5.6
40-in. *f*/7
80-in. *f*/7

(* Use only with fiducial marking attachment.)

Feed Spindle: Torque adjustable so that as film speed is altered, best results can be obtained through minor adjustment.

Timing Light: Double lamps provided. One can be used for standard time flash, and the other for event flash. NE66 lamps are used. It has been found that 135 volts will give better results with these lamps.

Viewfinders: Bright field telescopic and tracking finders will be provided.

Modifications to the camera to fill specific user needs will be made on request and to specification.

A camera of this type has long been needed in this country. In designing this camera a large number of factors have been taken into consideration. It is rugged and easy to manipulate. Its good picture quality fills the needs of research and development laboratories, the field, and the newcomers to high-speed photography, producers of entertainment and television.

Primary Color Filters With Interference Films

By H. H. SCHROEDER and A. F. TURNER

A set of vacuum-deposited thin-film multilayer transmission filters has been developed for use as highly efficient primaries in additive color projection. Light which is not transmitted is reflected. Consequently the filters can be used in high-illumination beams without overheating and changing color. Modification of spectrophotometric curves can be effected as desired in specific problems.

Through the use of vacuum-deposited multilayer interference films it is now possible from a practical and useful standpoint to design and manufacture transmission filters capable not only of supplanting colored glasses or gelatin in many cases, but also of producing color to specifications impossible with these older types of filters. Particularly the filters discussed herein correspond in hue to the Wratten three color projection primaries (Kodak Wratten Filter No. 47, blue; No. 59, green; No. 24, red). The Wratten filter curves are seen in Fig. 1 with theoretical curves of the interference coatings shown in Figs. 2a and 2b, illustrating two types of green-transmitting filters. The new filters are suitable for use as highly efficient primaries in additive color projection.

Presented on October 8, 1953, at the Society's Convention at New York by H. H. Schroeder (who read the paper) and A. F. Turner, Bausch & Lomb Optical Co., Rochester 2, N. Y.
(This paper was received August 31, 1953.)

Generally the filters are composed of alternating high- and low-index optical films deposited on a suitable substrate such as glass. Depending on particular requirements these types may have as many as 15 alternating layers. Through appropriate design and control of the relative thicknesses of the individual films predetermined optical specifications of wavelength and transmission may be achieved.

The materials used are all colorless, forming transparent films with practically no absorption in the visible and infrared. In the filters themselves reflectance plus transmittance totals 100% with the reflected portions being unused in the applications described.

In order to provide the best description of the properties of the filters from an engineering viewpoint a set of engineering spectrophotometric curves has been prepared, Figs. 3, 4, 5 and 6. These are based on actual experimental curves but have been simplified by smoothing so that nonessential irregularities are elimi-

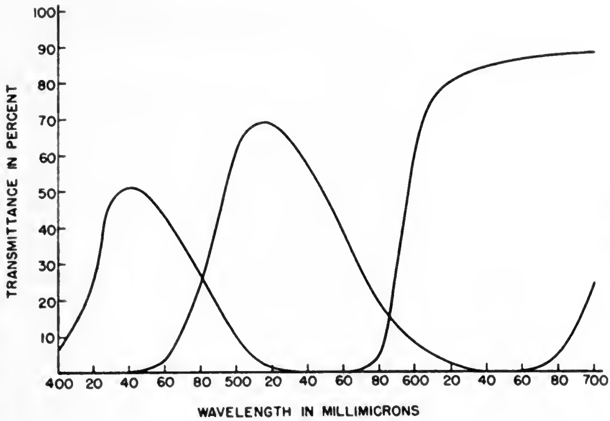


Fig. 1. Wratten three-color projection primaries.

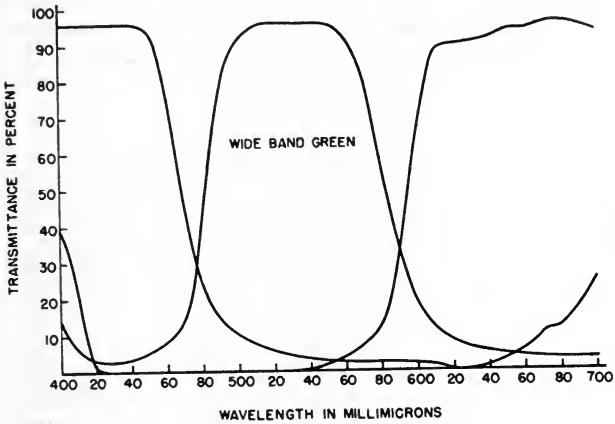


Fig. 2a. Multilayer interference coatings (theoretical curves).

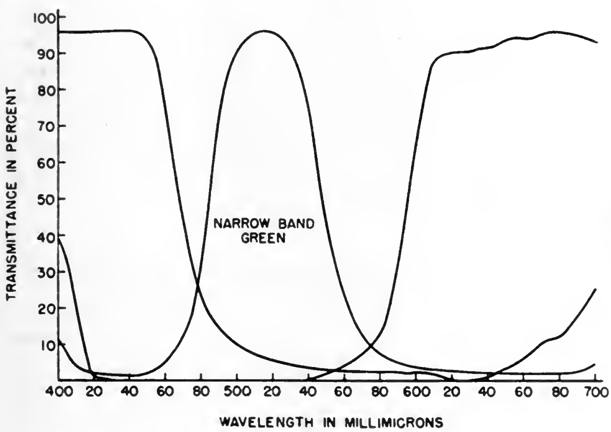


Fig. 2b. Multilayer interference coatings (theoretical curves).

nated. They will fit an experimental filter curve everywhere to within ±5%, exclusive of the background regions where the values shown represent maximum transmittances to be expected. This type of curve is considered to be sufficiently accurate for practical engineering purposes and has the advantage of simplicity of representation.

The blue-transmitting type is characterized in Fig. 3 by a maximum transmittance of 85% in the passband and a rejection-band transmittance of 2.5%. The degree of cutoff sharpness is described in terms of percent change in wavelength in progressing from the maximum transmission value to the first break in the curve in the low transmission region. Thus the blue has a cutoff factor of 6%. A slow rise in transmittance at the red end of the spectrum is attendant.

Figure 4 gives the characteristics of the wide-bandgreen-transmitting filter having a maximum transmittance value of 87.5%, rejection-region transmittances of 2.0 and 2.5% respectively for the blue and red, and cutoff factors of 4.5 and 5.5% for short and long wavelengths respectively.

The features of the red-transmitting type are illustrated in Fig. 5. The curve has 90% transmittance in the window, a drop to a value of 1% in the rejection part of the spectrum, and a cutoff factor of 9%. There is a sharp rise in transmittance at 420mμ to a value of 55% which extends to 400mμ.

In Fig. 6 the narrow-band green type is described. This filter involves a different film combination with a window transmittance comparable to that of the wide band but of less width at the top. There is a background value of 2% for both rejection regions which extends for the most part to the limits of the visible spectrum.

The two types of green filters discussed are indicative of what one may expect in the way of flexibility from multilayer interference coatings. In the same manner in which a design change brought about a change in width from one green filter to the other, one could readily change the type of film combination to effect more gradual cutting filters for the blue and red types. By changing thicknesses in the existing types, shifts to longer or shorter wavelengths to obtain different color characteristics can be achieved. The degree of sharpness in the cutoffs of the filters shown is obtained through the use of a limited number of layers, in this case fifteen. Sharper cutting types involving more films can be designed if desired.

In the chromaticity diagram of Fig. 7 the multilayer primaries define the color triangle shown, with the Wratten filters indicated by the triangular points. The Wratten filters show a greater saturation for the blue and red, while the multilayer green-coating saturation is slightly greater than that of the Wratten.

Also indicated in Fig. 7 is a definitive point for the narrow-band green which has a brightness slightly higher than the Wratten green with considerably more saturation.

In all cases the brightness values of the multilayer filters are above those of the Wratten filters, being approximately 60% greater for the blue, 71% more in the case of the green, and 6% more for the red. Colorimetric data comparing the two types of filters are shown in Table I.

Table I. Colorimetric Data—Multilayer Interference Coating vs. Wratten Filter

	Dominant λ-mμ			Purity (%)			Brightness (%)		
	Blue	Green	Red	Blue	Green	Red	Blue	Green	Red
Multilayer	446	542	614	89.7	65.6	88.0	4.1	59.1	17.1
Wratten filter	463	539	611	97.0	63.5	100.0	2.5	34.5	16.1

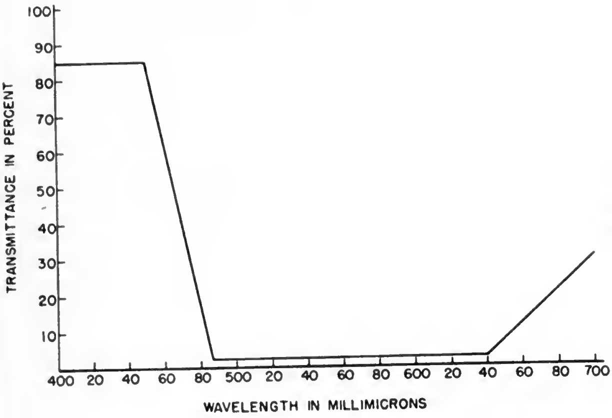


Fig. 3. Blue transmitting filter (engineering curve).

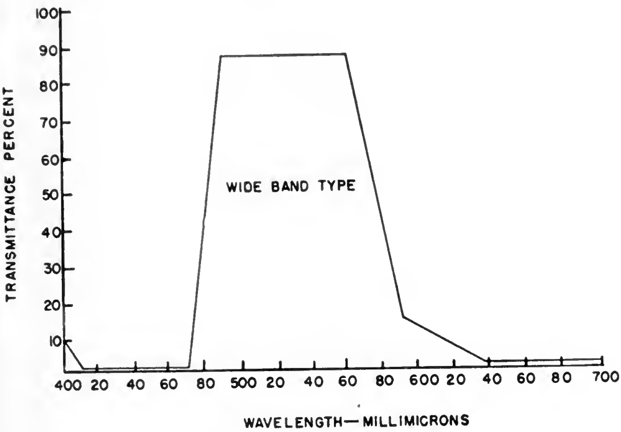


Fig. 4. Green transmitting filter (engineering curve).

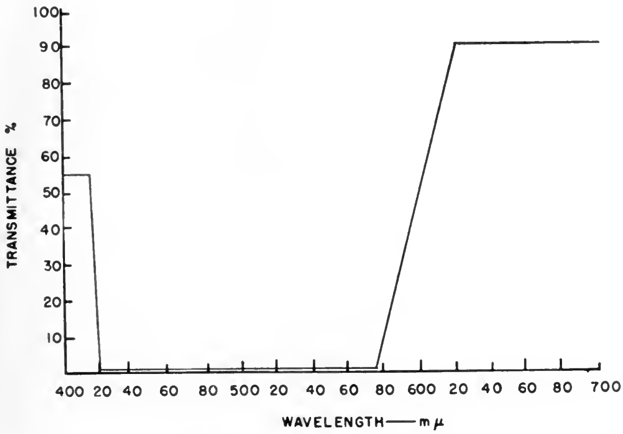


Fig. 5. Red transmitting filter (engineering curve).

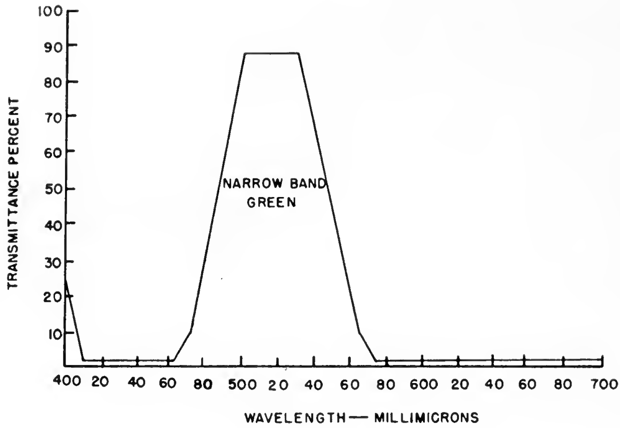


Fig. 6. Green transmitting filter (engineering curve).

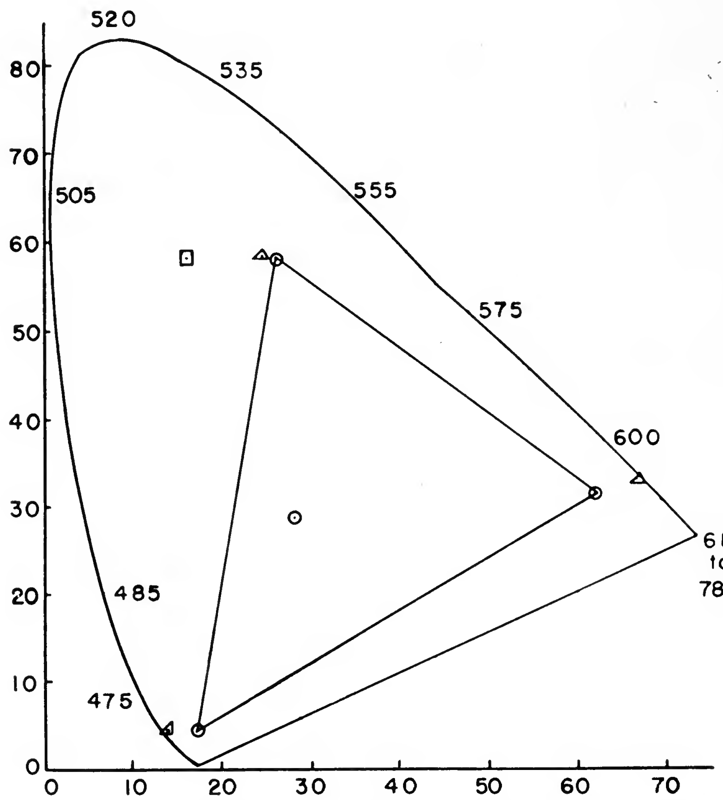


Fig. 7. Chromaticity diagram: ⊙ = multilayer interference coatings ◬ = Wratten filters ⊡ = narrow-band green filter.

One of the most important features of the vacuum-deposited multilayer interference coatings is their stability with respect to color shift upon aging, or exposure to elevated temperatures, whereas glass or gelatin filters are prone to fade or shift hue. This feature has proven itself under actual operating conditions in high-intensity projection equipment.

The coatings can be readily cleaned of smudges and fingerprints with a clean soft cloth or washed in a detergent solution followed by rinsing and drying with a clean soft cloth. Should abrasive particles be present scratches may occur in the film, but no general breaking down of the coating which would affect the function of the filter will occur. Generally, one should treat the filters as one would care for a good optical surface.

In conclusion it can be said that by means of multilayer interference coatings primary color filters suitable for additive color projection and having particular advantages over glass and gelatin have been developed. The filters offer satisfactory saturation, afford high brightness values, and are colorimetrically stable with temperature.

The authors are grateful to R. Kraft for technical assistance in the preparation of the filters, and to L. I. Epstein for theoretical contributions.

Discussion

John G. Stott (Du-Art Film Laboratories, Inc.): Why were not actual spectrophotometric curves of the filters shown rather than theoretical engineering curves?

Mr. Schroeder: It seemed that from the standpoint of practicability it might be more useful to show these engineering curves. They were taken directly from the experimental curves, with minor deviations eliminated. You could expect within 5% to duplicate these engineering curves. We could have shown the actual curves just as well, but the engineering curves seem more useful because in many cases you see these requirements defined in straight-line values rather than in curves.

A 35mm Stereo Cine Camera

By C. E. BEACHELL

This paper deals with the design and construction of a 35mm stereo cine camera outlining the optimum facilities required, the problems encountered in design of the camera and how they were solved, and the technique used in shooting stereo motion pictures with this camera.

A STEREO CINE CAMERA should have the following features:

1. Cameras should be rigidly mounted on the bedplate so as to withstand normal shocks encountered in use and transit without going out of calibration or synchronization.
2. Interaxial control must be possible from a minimum of approximately the physical width of the film (1.5 in.) to at least 12 in.
3. Convergence control which may be calibrated in the same manner as the focus of a lens, i.e. in feet in front of the camera, should be included. This calibration must remain accurate throughout the range of interaxial distance and preferably remain fixed as the interaxial distance is changed.
4. A binocular (stereo) viewfinder should be provided as well as the conventional flat viewfinder.
5. Shutters should be exactly synchronized with each other.
6. Camera should be removable from the carriages without loss of synchronization when replaced.
7. Motors should be provided for synchronous operation, battery operation with variable indicated frame rate and stop frame for animation work.
8. Camera must accommodate both 400- and 1000-ft magazines.
9. Weight of the camera should be kept to a minimum for ease of handling.

After considering various methods of obtaining small interaxial distance it was decided that mirrors or prisms in the optical path should not be used because:

1. They limit the use of wide-angle lenses.
2. There is loss of light in transmission thus effectively reducing lens speed.
3. A single mirror or prism produces a reverted negative image.
4. The use of 50% transmission mirrors required some color correction which means that light reaching the film is effectively less than 50% of the scene brightness.

It was decided to design this stereo camera using direct objective systems and separate negatives for left and right images. The minimum interaxial

Presented on October 8, 1953, at the Society's Convention at New York by C. E. Beachell, National Film Board of Canada, 35 John St., Ottawa, Ont., Canada.
(This paper was received Sept. 24, 1953.)

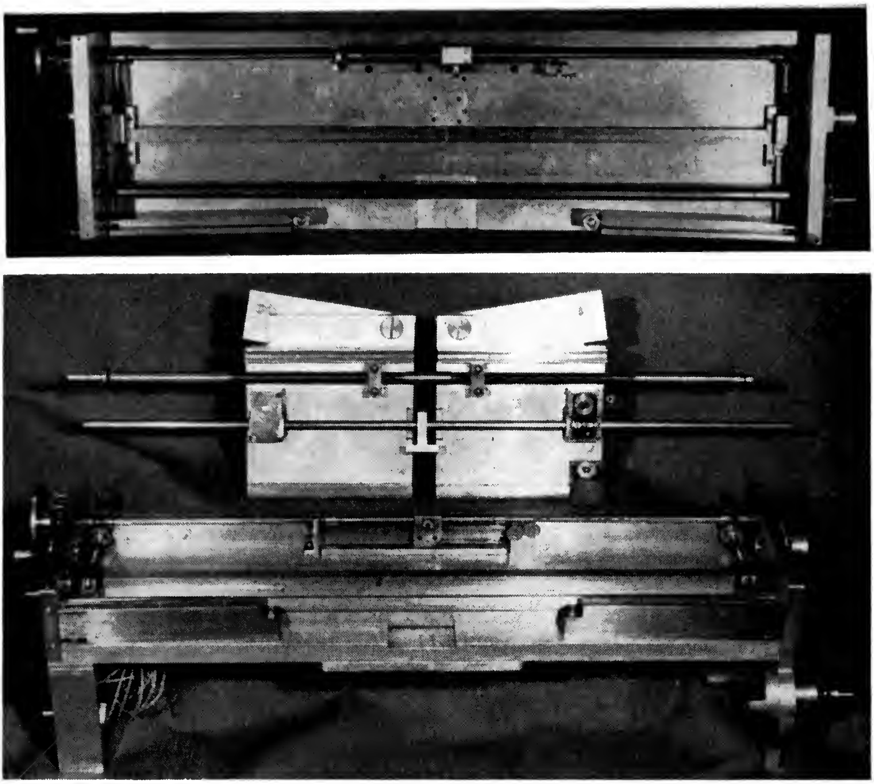


Fig. 1. Above, bedplate; below, bedplate and carriages.

distance obtainable was just under 2 in. due to the width of the films and the thickness of the camera doors. Conveniently this distance is approximately the diameter of most standard lenses which would be used on the camera.

In this camera the bedplate (Fig. 1) is cast duraluminum $\frac{3}{4}$ in. thick $\times$ 24 in. long $\times$ $7\frac{1}{4}$ in. wide. Three steel rails $\frac{1}{2}$ in. thick are inserted into the bedplate to a depth of $\frac{1}{8}$ in. The front rail is V'd on top and controls the movement of the camera carriages so that they remain parallel to each other. The center rail is for strengthening of the bed; and the rear rail, which is flat on top, supports the weight of the back of the camera carriages. Keyways are cut into the sides of the front and back rails and steel clips which are bolted to the rails of the carriage are hooked into the keyways. This arrangement prevents any lifting of the camera carriages from the rails which control their position.

On each carriage the camera mounting plate is pivoted at a point immediately under the center of the film plane and rotates about this point to control convergence (Fig. 2). The cameras are mounted and doweled on these rotor plates.

Interaxial Control

Interaxial control is achieved by means of a shaft having a right- and a lefthand thread cut in a portion of each

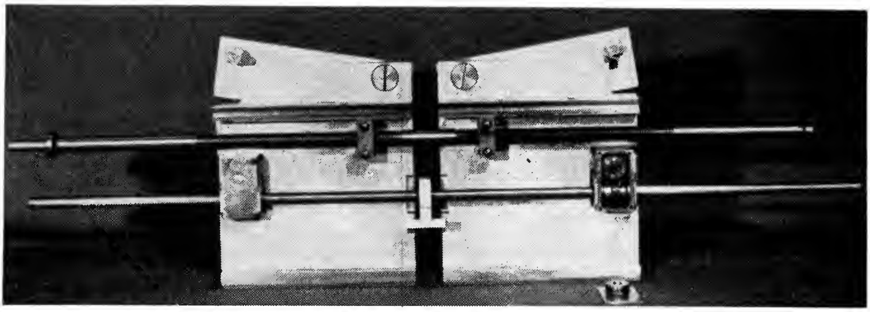


Fig. 2. Underside of carriages, showing interaxial control, main driveshaft, gearboxes and pivoted mounting plates.

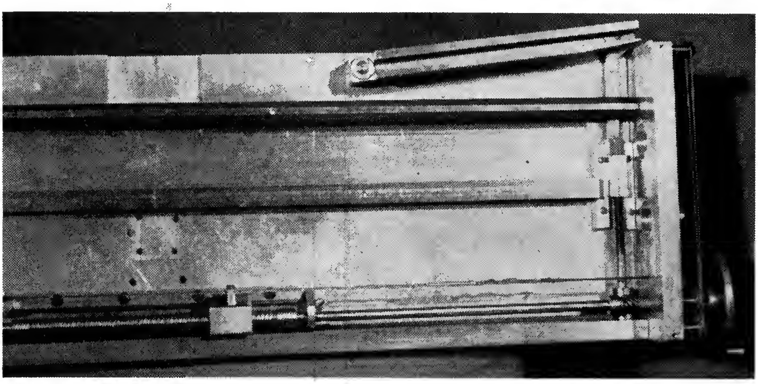


Fig. 3. Convergence control mechanism. Note angled control rail.

end of the shaft. A split nut is bolted to each carriage and engaged with the right and left threads in the lead screw respectively. Thus, when the lead screw is turned in one direction, both carriages are moved away from the center of the bedplate. By reversing the rotation of the lead screw, they are drawn together at the center. Mounted on the bedplate is a calibrated scale on which the movement of $\frac{1}{2}$ in. equals 1 in. The pointer is mounted on the back of the right-hand carriage. The range of interaxial distance is 1.95 in. to 13 in. The wider interaxial distances are used for longer lenses and for long shots with shorter lenses provided there is no resolvable information in the foreground. For example, it was found that if you shoot a subject, say, 15 ft distant from the camera and converge on the subject with a 2-in. lens and an interaxial distance of $2\frac{1}{2}$ in., then the same perception of thickness of the subject can be achieved at a distance of 30 ft using an interaxial distance of 5 in. and a 4-in. lens. Therefore, as the lens focal length is doubled, the interaxial distance must be doubled to maintain the same perception of depth or thickness.

Convergence Control

Convergence is controlled by two rails which are mounted immediately in front of the V rail (Fig. 3). These rails each pivot at a point 5 in. to the right and left respectively of the center line of the camera bed. The free ends of these rails are moved forward for convergence and backward for divergence through a gearing system and two lead screws so arranged that one rotation of the control handle moves the end of the rail 0.025 in. while the convergence indicator moves 0.1 in.

A point on the rotor plate 5 in. to the right of the center of the film plane of the right camera and to the left of the left camera center is engaged with a slot in its respective control rail. These points are the control points of the rotor plates. Thus, in this arrangement the pivot points of the rotor move along a line 90° to the center line of the camera bed. The control points of the rotor plates follow a line along the control rail, thus maintaining constant convergence distance in front of the camera with negligible error throughout the full range of interaxial distance when the angle of the control rail is kept constant. This is proven by the equation:

$$\text{Max } D_c \text{ in.} - \text{Min } D_c \text{ in.} = \cot \beta - 6.5 \cot \theta$$ (see Appendix 1)

where β is minimum convergence angle and θ is maximum convergence angle, with the control rail angle constant and minimum and maximum interaxial distances in inches. A general formula for convergence angle at any interaxial distance and any angle of the control rail is given in the equation:

$$\theta = \alpha + \sin^{-1}\left[\left(\frac{I_c - 10}{10}\right) \sin \alpha\right]$$ (see Appendix 1)

when θ is the angle of convergence;
α is the angle of control rail; and
I_c is the interaxial distance in inches

The maximum convergence distance error encountered throughout the complete range of convergence and interaxial distance was found to be 1.3 in. at $3\frac{1}{2}$ ft which is actually less than the error involved in reading the calibration and therefore negligible. The maximum error at 5 ft is 0.14 in. This figure reduces as convergence distance approaches infinity where the error is 0.

This mechanism on the camera removes the necessity of making complicated calculations for convergence angle when shooting stereo cine pictures, thus saving a lot of time and reducing the probability of bad takes due to errors in calculations. Calculation for nearness and thickness factors can be made readily with the use of the Motion Picture Research Council 3D calculator.

In this camera, the silent aperture is used. Shots can be composed so that the essential picture material lies in an area suitable for 1.85:1 aspect ratio.

Development work is proceeding on a binocular viewfinder which will be mounted so that its objective systems follow faithfully all changes of the interaxial and/or convergence settings of the camera. The ocular systems provide an upright stereo picture with the same viewing angle as that of viewing a 20-ft screen from a distance of 60 ft. With this device, results of calculations may be readily verified with regard to distortions and painful background divergences. As soon as the construction of the viewfinder is completed and tested a companion paper will be submitted.

Optics

This camera is so designed that the optics are direct, thus permitting the use of conventional matched pairs of lenses from extremely short focal length, e.g. 20 mm, to telephoto. The only limiting factor in the short focal length lenses is that they must not have a physical radius greater than one-half the minimum interaxial distance at which they are to be used. The use of mirrors and prisms was avoided in design for the reasons mentioned previously.

The Driving Mechanism

The driving mechanism consists of a long shaft which runs the length of the camera bed and which has a keyway cut in the portion at each end over

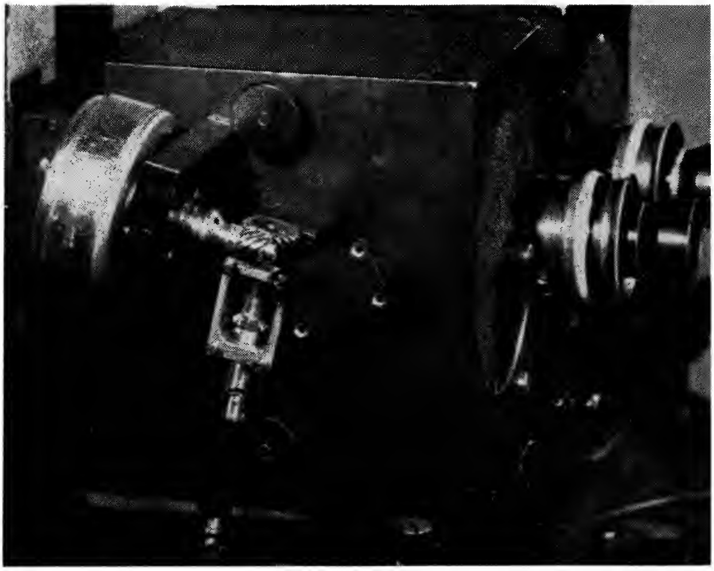


Fig. 4. Drive mechanism: telescoping shaft, gearbox and tachometer.

which the camera carriages move. This keyway drives a set of gears which have a 1:1 ratio and changes the direction of the shaft 90°; helical gears are used to avoid noise. The camera is driven through two universal joints and a telescoping shaft to a 90° 1:1 gearbox mounted on its side (Fig. 4). The universal joints and telescoping shaft accommodate the movement of the camera for convergence. The shaft from the camera gearbox then drives the camera in the conventional manner.

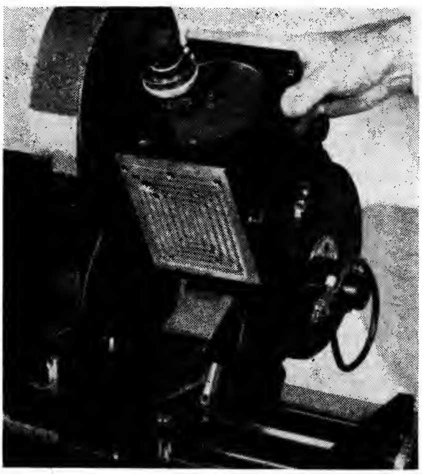


Fig. 5. Left camera lifted from rotor plate.

As this camera was an experimental project it was decided to use a pair of Bell & Howell Eyemo movements, rather than spend a large amount of money on registration movements. These were modified and one of them now is mounted upside down and runs backwards. It is planned — if stereo production demand warrants it — to install registration movements in this camera in the future, but for the present the Eyemo movements are satisfactory although somewhat noisy. To date no attempt has been made to blimp this camera as it was basically an experiment in stereoscopy.

With this type of drive it is impossible for the shutters to get out of synchronism (Fig. 5). When the cameras are removed from the rotor plate for any reason, the drive breaks at the tele-

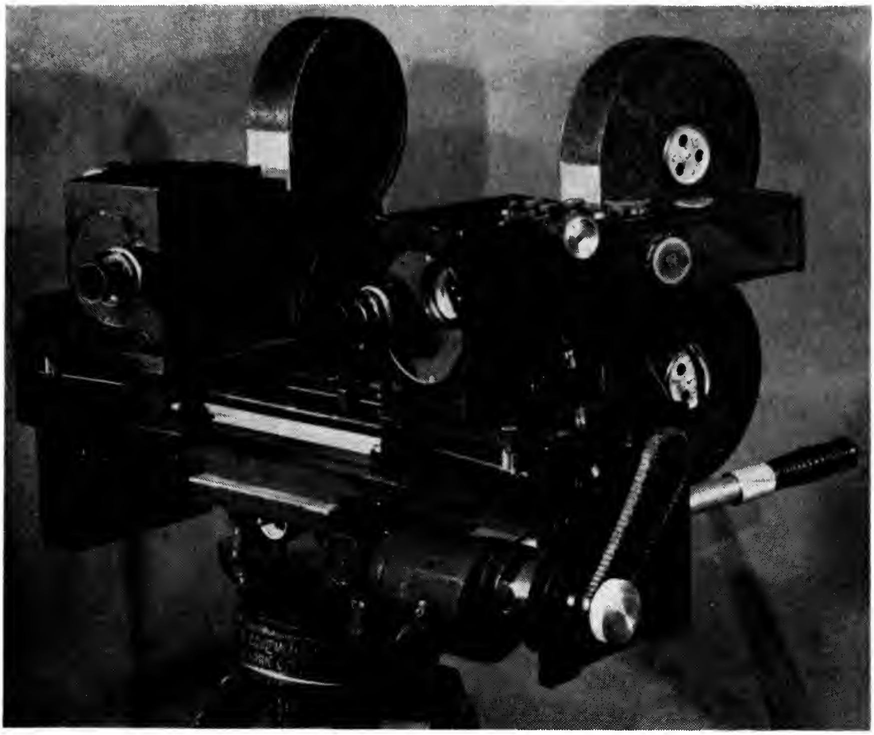


Fig. 6. General view of camera.

scoping shaft and can be reassembled only with shutters interlocked.

Takeup is driven by independently controlled motors.

Footage is indicated by a counter driven by a gearing arrangement on the end of the main driveshaft.

All controls and indicators in connection with the camera are on the right rear corner of the bed conveniently located for the camera assistant.

This prototype model camera is not equipped with a follow focus control, but, if stereo production warrants, this feature can be included without too much difficulty.

The motor mounting is a standard Bell & Howell (Fig. 6). Variable-speed battery motors or 3-phase synchronous motors can be readily used. Motor speed for 24 frames/sec is 1440 rpm. The motor is linked to the main driveshaft by a silent chain with 2:1 reduction sprockets so that the main drive rotates at 720 rpm. This slower speed was used to reduce noise. For animation work an Acme Stop Frame Motor is readily adaptable.

The camera will accommodate either 400- or 1000-ft Bell & Howell magazines. The weight of the complete camera, less magazines, is 86½ lb.

Conclusion

In stereo shooting it has been our experience that convergence should never be changed during a shot. When convergence follows a moving figure, it produces the very unlikely and somewhat disturbing effect of the set moving in and out of the theater while the actor remains on the screen. The same effect is apparent although to a lesser degree when interaxial distance is changed and convergence remains constant. We have found that the only time either control should be moved during a shot is when the camera is either being panned or tilted. This movement covers the disturbing effect of other changes.

In this camera the following design features have been achieved:

1. Rigid mounting with complete flexibility for changes of interaxial distance and convergence.
2. Objective systems are direct, permitting the use of very wide angle lenses with full light transmission.
3. Calibrated interaxial control from 1.95 in. to 13 in.
4. Convergence control accurately calibrated in feet in front of the camera ranging from 3.5 ft to infinity. Calibration remains accurate throughout full range of interaxial distances.
5. Exact mechanical synchronization of shutters.
6. Cameras may be dismounted for routine maintenance, transportation, etc., and remounted without loss of synchronization.
7. Motors are provided for battery, synchronous and stop-frame operation.
8. 400- or 1000-ft magazines may be used on the camera.

Regardless of the future of stereo cine pictures in the entertainment field, there is a tremendous future for the medium in the instructional film field. This field of film making is our primary interest at the National Film Board of Canada.

Acknowledgments

Thanks are due to the following personnel of the National Film Board: Ken Carey, for his assistance in the design and final tests of the camera; Fred Exeter and Les Dupuis for their many helpful suggestions and work in constructing the camera bed; and Nic Culic and Wilf Sauve for their work on the camera movements.

APPENDIX

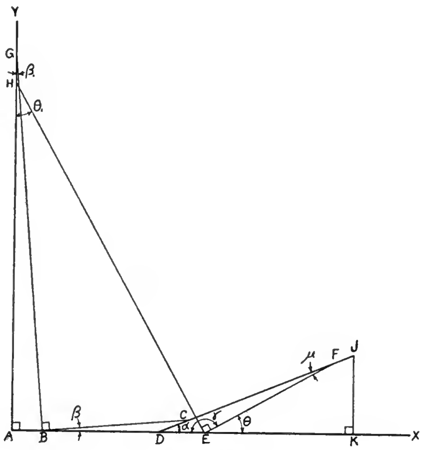


Figure 7.

Figure 7 is a geometric illustration of the right camera.

AY is the *c/L* of the stereo camera bed.

AX is a line in the film plane and || to the bed rails.

DJ is a line along the right control rail.

BD and *EF* are the positions of a line between the pivot point and the control point of the right camera pivot plate at min. and max. interaxial distance.

JK is varied to control angle α.

$AD = BC = EF = 5$ in. by construction.

$AB = 1$ in. " "

$AE = 6.5$ in. " "

$DK = 6.5$ in. " "

$DE = 1.5$ in. " "

Ic is interaxial distance.

$$DE = \frac{Ic}{2} - AD$$

To find $\angle\theta$:

In the triangle *DFE*

$$\frac{EF}{\sin\alpha} = \frac{DE}{\sin\mu}$$

$$\sin \mu = \frac{DE \sin \alpha}{EF}$$

$$\gamma = 180 - \left[\alpha + \sin^{-1}\left(\frac{DE \sin \alpha}{EF}\right)\right]$$

But $\gamma = 180 - \theta$

$$\therefore \quad \theta = \left[\alpha + \sin^{-1}\left(\frac{DE \sin \alpha}{EF}\right)\right]$$

But $DE = \frac{Ic}{2} - 5$ and $EF = 5$

$$\therefore \quad \theta = \alpha + \sin^{-1}\left[\left(\frac{\frac{Ic}{2} - 5}{5}\right) \sin \alpha\right]$$

$$\theta = \alpha + \sin^{-1}\left[\left(\frac{Ic - 10}{10}\right) \sin \alpha\right]$$

When $\angle \alpha$ remains constant and $\frac{Ic}{2}$ changes from AB to AE,

$AG = \text{Max. } D_c$
$AH = \text{Min. } D_c$
Dc = Distance to convergence in inches.

It can be shown that:

$$\angle \beta = \angle \beta_1$$

and

$$\angle \theta = \angle \theta_1$$

In the Δ AGB

$$\cot \beta_1 = \frac{AG}{AB}$$

$$AG = AB \cot \beta_1 \qquad \text{(I)}$$

In the Δ AHE

$$\cot \theta_1 = \frac{AH}{AE}$$

$$AH = AE \cot \theta_1 \qquad \text{(II)}$$

Subtracting (II) from (I)

$$AG - AH = AB \cot \beta_1 - AE \cot \theta_1$$

By construction:

$$AB = 1 \text{ in.} = {}^1/_2 \text{ Min. } I_c$$
$$AE = 6.5 \text{ in.} = {}^1/_2 \text{ Max. } I_c$$

$\therefore$ Max. D_c − Min. D_c = $\cot \beta - 6.5 \cot \theta$

To find JK for any $\angle \alpha$ from 0° to 7°:

In the Δ JDK

$$\text{Tan } \alpha = \frac{JK}{DK}$$

$$JK = DK \tan \alpha$$

But $DK = 6.5$ in.
$\therefore \quad JK = 6.5 \text{ Tan } \alpha$

Projector for 16mm Optical and Magnetic Sound

By JOHN A. RODGERS

In addition to reproducing sound from conventional optical tracks, this projector is capable of recording and playing back magnetic oxide tracks applied to either single- or double-perforated 16mm films. The important aspects of the mechanical and electrical design are described, showing their relation to the performance of the projector.

Successful design requires a knowledge of the intended use of the product, the necessary performance characteristics and the special conditions of operation. This information must be sought out and carefully considered if the design is to prove satisfactory. Since magnetic sound is new to 16mm film projectors, the requirements are less easily determined and to some extent must be anticipated for the various users by the designers.

General Description

A projector of this type must satisfy the requirements of the conventional optical sound machine and in addition provide the means for recording and reproducing sound magnetically, preferably on all types of 16mm film. It is also essential that all operations be simple and as nearly foolproof as possible.

The compactness of the complete projector, which measures $16\frac{1}{2}$ by $10\frac{1}{2}$ by $12\frac{1}{2}$ in. and weighs 42 lb, makes it readily portable and its power output of 7 w is sufficient for most audiences. It is installed in a durable fabric-covered case, which has a removable side that serves as a baffle for the loudspeaker. This construction is shown in Fig. 1.

Presented on October 7, 1952, at the Society's Convention at Washington, D.C., by John A. Rodgers, Eastman Kodak Company, Camera Works, 333 State St., Rochester 4, N.Y.
(This paper was received Sept. 15, 1953.)

Operation

The controls on the amplifier panel shown in Fig. 2 have been reduced to a minimum and grouped for ease of use. Figure 3 shows the knob controlling the positions of the record and erase heads for the three conditions of operation. In the "Optical" position both heads are away from the sound track. In the "Magnetic Play" position the record head is in contact with the track, while the erase remains away. Both heads are in contact in the "Magnetic Record" position. The metal flag attached to the control shaft prevents the operator from threading the film around the sound drum until he has moved the record and erase heads out of the way by turning to "Optical."

Optical sound film may be reproduced by setting the head control and the amplifier selector switch to "Optical" and

Fig. 1. Complete projector showing speaker and microphone.

operating the volume and tone controls in the usual manner. If the head control were inadvertently turned to one of the other positions, where scratching of the sound track could occur, no sound would be reproduced, since the switch on the rear of the control would disconnect the exciter lamp.

The projector amplifier may be used as a public address system when the microphone is attached and the selector switch turned to "Optical." In a similar manner a record player connected at the "Phono Input" makes use of the projector sound system.

Magnetic sound tracks may be reproduced when the head control and selector switch are turned to "Magnetic Playback." Recording is accomplished in several ways depending upon the results desired and the extensiveness of auxiliary equipment available. For voice recording the microphone is attached and the head control and selector switch set to "Magnetic Record." The volume control is adjusted so that the neon indicator flashes on peaks of the voice signal and under these conditions

Fig. 2. Amplifier control panel.

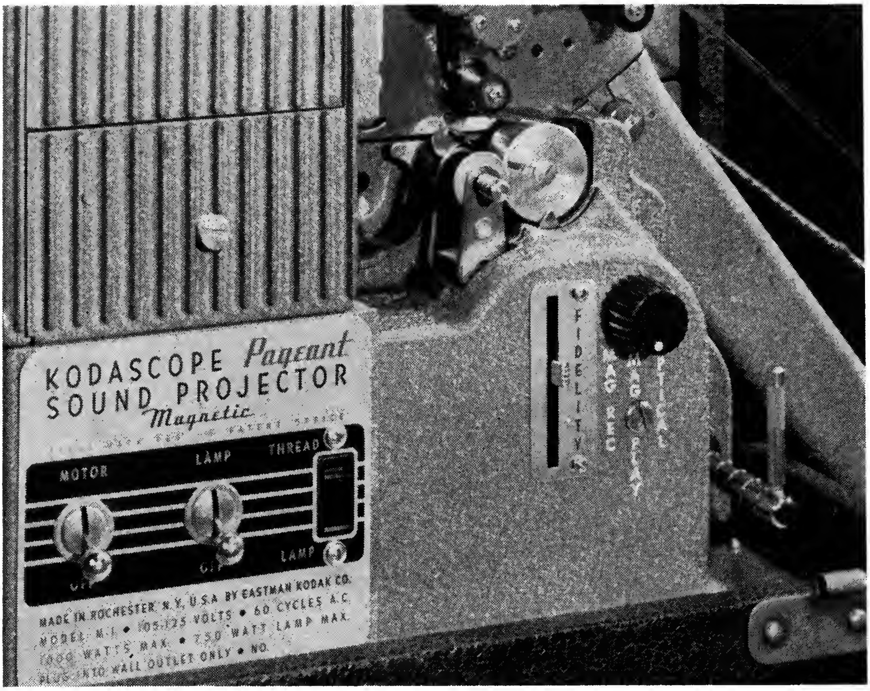


Fig. 3. Sound head showing control switch.

all previously recorded sound is erased from the track.

If it becomes necessary to alter a section of the recording, the projector can be reversed by means of the knob shown in Fig. 2 and the film run back to a point somewhat beyond the part to be changed, with the selector switch in the "Magnetic Playback" position. The machine is then run forward and when the section to be changed arrives, it is only necessary to return the selector switch to "Record" and proceed with the revised recording. Because the erase head is located immediately ahead of the record head, erasure is restricted to the section of track that is to be re-recorded.

Music may be recorded with the microphone placed in front of the source or it may be applied electrically by the attachment of a record player or tape recorder at the "Phono Input" socket. The signal level may then be adjusted by means of the "Phono" control as shown in Fig. 2. Since this control is independent of the master volume control, by which the microphone input level is adjusted, it is possible to mix voice and music as desired.

During recording the loudspeaker can be used for monitoring, since the recorded signal is audible but at a level sufficiently reduced to avoid coupling with the microphone. Headphones plugged into the speaker socket provide a more satisfactory method of monitoring where two or more people are engaged in making a recording involving the mixing of voices and music.

Partial Erase

An alternative method of recording divides the operation into two steps and is usually considered more convenient. In this the music and sound effects are first recorded at full level and the voice commentary added during a second recording with the head control in the "Magnetic Playback" position. Since the erase head is not in contact with the track during the voice recording, the previously recorded music is not erased. However, it is reduced automatically to the proper level for background music.

Safety Devices

Wherever possible safety devices are incorporated so that the operator will not inadvertently damage a recorded track, but these have been designed in such a way that they do not unduly complicate the operation of the projector. The amplifier selector switch cannot be turned into the "Record" position unless the knob is partially withdrawn. This is accomplished simply by the addition of a pin at the back of the knob that interferes with a stud on the panel behind it. During recording operations this knob may be interchanged with one of the others for convenience.

When the selector switch and head control are at "Magnetic Record," the red warning light on the amplifier panel is on, indicating that magnetic tracks will be erased. The light gives additional assurance that the conditions for recording are correct. If the head control is then moved to "Magnetic Play," the warning light will be on but at a lower intensity to show that a track can be partially erased.

The record and erase heads are protected during threading by the metal flag on the head-control shaft which prevents insertion of the film until the heads are moved away. As has also been mentioned previously the exciter lamp for optical sound reproduction remains off until the heads are removed from the film. Therefore scratching of optical sound track is virtually impossible.

To reverse the projector the reversing switch, which is equipped with a return spring, is operated and the motor started. The reversing switch can then be allowed to return to the forward position and the motor will continue to run backward until shut off because the switch operates only on the starting winding of the split-phase motor. This feature saves time and prevents mistakes by making it unnecessary for the operator to remember the reversing switch when forward motion is again required.

Amplifier Circuits

A miniature pentode (Fig. 4) provides high voltage gain for the first stage and the input is connected to the phototube, the magnetic-head transformer, and the microphone in the order of positions of the selector switch. Its output is applied to the volume control where the signal is then mixed with the signal coming from the phono-level control and applied to the second and third stages, a high-gain miniature dual triode. Next a low-gain miniature triode is used in a phase-splitter circuit to drive the push-pull output pentodes. Inverse feedback stabilizes the output stage and reduces the amplifier internal impedance. The tone control reduces the low frequencies when operated in a counterclockwise direction from "Normal" and attenuates the high frequencies in the clockwise position. This circuit is disconnected during recording.

The oscillator supplies current to the exciter lamp for optical sound reproduction and to the erase head and bias winding for magnetic recording. It is of the Hartley type using a miniature triode and a powdered iron core coil tuned to about 40 kc. When the selector switch is turned from "Record" to "Magnetic Playback," the plate supply for the oscillator is disconnected and this part of the switching takes place a short interval ahead of the other circuit switching. A condenser connected between the oscillator plate and ground stores enough energy to cause the high-frequency current to decay over several cycles when the plate supply is switched off. This not only eliminates switching clicks in the recording but avoids possible magnetiza-

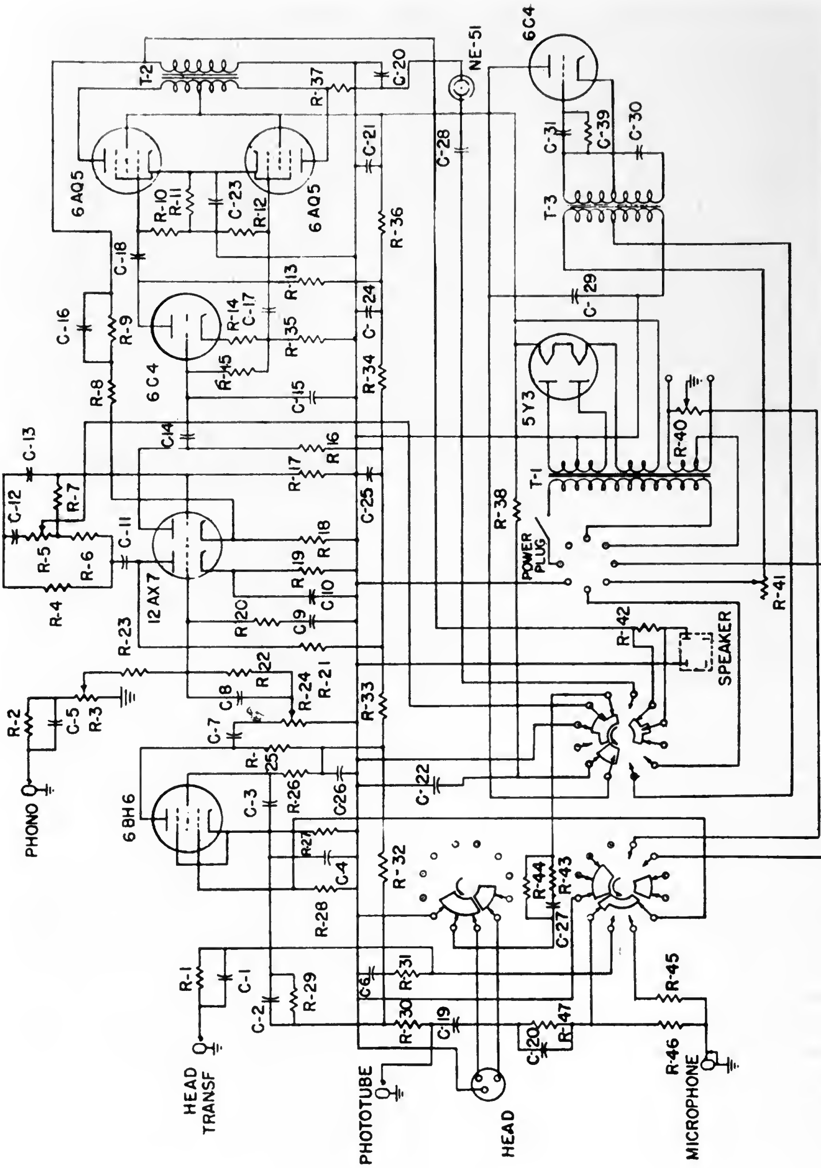


Fig. 4. Optical-magnetic amplifier schematic.

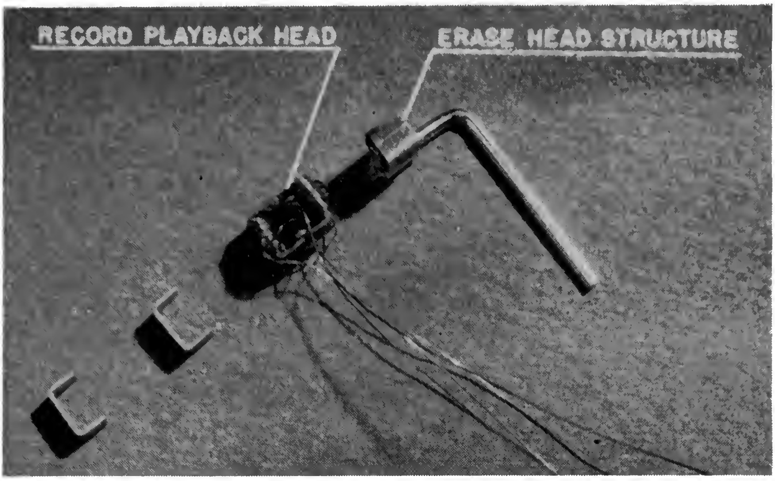


Fig. 5. Magnetic sound record and erase heads.

tion of the heads by preventing a discontinuity in the waveform of the bias current.

Magnetic Heads

The erase and record heads, shown in Fig. 5, are similarly constructed of pairs of 0.015-in. thick mu-metal U-shaped sections soldered at the front and back gaps. The front gaps are provided with copper spacers. The erase head has a 0.005-in. spacer and is 0.125-in. wide to overlap the 0.100-in. track. Since it requires only 20 coil turns, it has been found feasible to wind it after assembly.

The record-head sections are wound with 100 turns each on a special machine and then positioned in a fixture and soldered together. The spacer in the front gap is 0.0004-in. thick and the head is 0.090-in. wide. The front faces of both heads are ground and polished flat and the bias turns added to the record head prior to its installation and potting in its metal shield.

Head Mounting

Both the record and erase heads are mounted on pivoted arms (Fig. 6) actuated by a cam on the control shaft and pulled into position by coil springs. The rear of the shaft is equipped with positioning detents and a switch for controlling the warning light and the exciter lamp.

Adjustment of the erase head is obtained by provision for sliding its support arm in the sleeve on the pivoted arm and by rotating it. A set-screw at location "A" in the sleeve is then tightened to lock it in place. The actual screw does not appear in the figure.

The azimuth alignment of the record head is accomplished by loosening screws "B," which hold the shield in which the head is potted, and rotating the head to obtain a maximum signal output from a special 8000-cycle azimuth adjustment track.

Screw "C" forces a nylon pin against the record-head mounting rod and, when this is released slightly, two other adjustments can be made. Operation of screw "D" against the arm in the rod rotates the head so that it may be positioned correctly for contact across the entire width of the track. The screwdriver adjustment at "E" actuates an eccentric pin engaging a slot in the support rod to move it up and down. This permits the head gap to be placed in contact with the magnetic track.

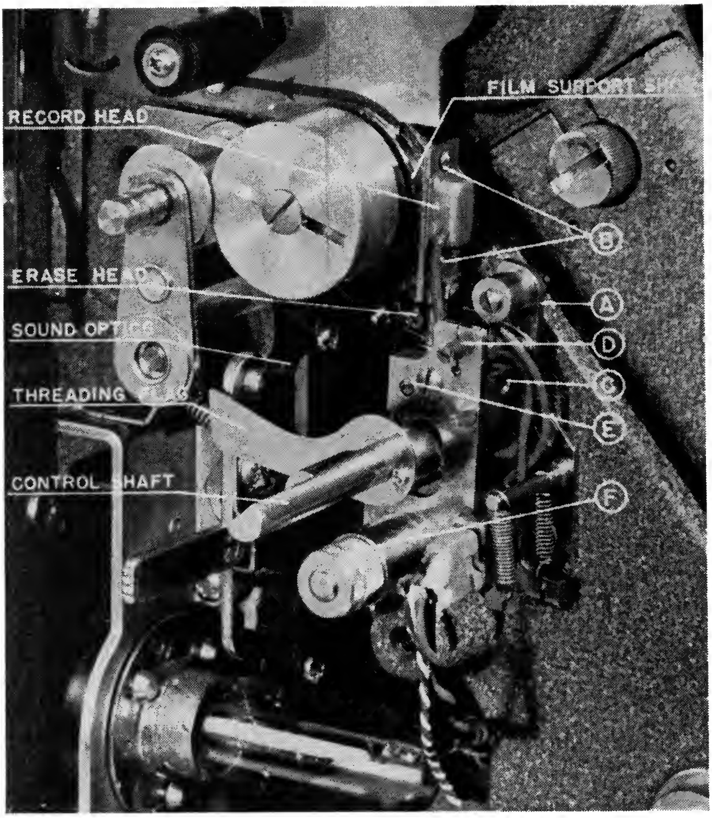


Fig. 6. Sound head with cover removed.

The head mounting arms are pivoted on a shaft threaded at the outer end for adjusting nut "F" and held away from the mounting plate by a coil spring. This nut may be turned to center the heads on the track.

Sound Stabilization

Frequency variations in the form of wow or flutter are less than 0.4% by reason of the large flywheel and the damping roller located between the sound drum and sound sprocket. Variations in the amplitude of the sound on "Magnetic" are caused by improper contact between the head gap and the track. These are of the order of 0.2 db at 1000 cycles and vary with the quality of the track itself. At higher frequencies these variations are considerably greater. It has been found that a pressure of about 1 oz is sufficient for good contact between the head and the track and that greater pressure produces no improvement in the amplitude variations but hastens the wear of the head.

Double-Perforated Film

There is an obvious need for sound recording on the double-perforated silent type of 16mm film in that it immediately opens the door to both the amateur and professional who already have film records of this type. This precludes the necessity for expensive duplicating on single-perforated sound type of film and

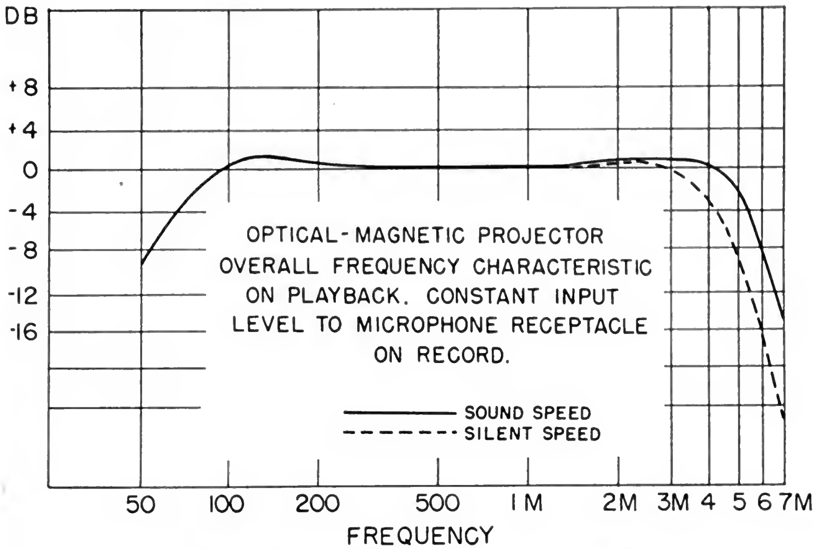


Fig. 7. Record-playback frequency characteristic.

also allows the use of any 16mm motion-picture camera. Furthermore, the projector can be operated at silent speed to suit the action in the picture and the sound will be satisfactory, although there will be some sacrifice in the high-frequency response, as can be seen in Fig. 7.

Optical sound-track scanning requires that the film project beyond the rear of the sound drum and it has been found necessary to support the film at this edge for satisfactory operation when double-perforated film with its 0.030-in. wide magnetic track is used. Therefore, a film support shoe, shown in Fig. 6, has been added. This shoe is in contact with the film at the rear edge when the record head is on the track and is effective in minimizing the sprocket-hole modulation that would otherwise result in unsatisfactory sound quality.

This provision for the operation of the projector with double-perforated film also assures improved results with distorted film and uneven magnetic tracks, where the amplitude variations would otherwise be too great for satisfactory sound.

Because of its intermittent character, speech may be recorded and played back on the double-perforated type of film with tolerable results even when no special effort has been made for reducing the sprocket-hole modulation. However, this is not the case with music, where even small disturbances in the uniformity of the sound render the quality noticeably unsatisfactory.

System Noise

The amplifier sensitivity is sufficient to afford a reserve gain of about 20 db when playing back a 0.100-in. wide magnetic-track recorder fully. This is considered necessary when it is realized that the 0.030-in. track supplies about 12 db less playback level. There are also variations in output from tracks applied by different manufacturers.

With such high sensitivity in the amplifier the problem of keeping the noise down to a tolerable level becomes difficult and extreme care must be observed to prevent the stray fields from the motor and power transformer from coupling with the amplifier circuits, input transformer, head and cables.

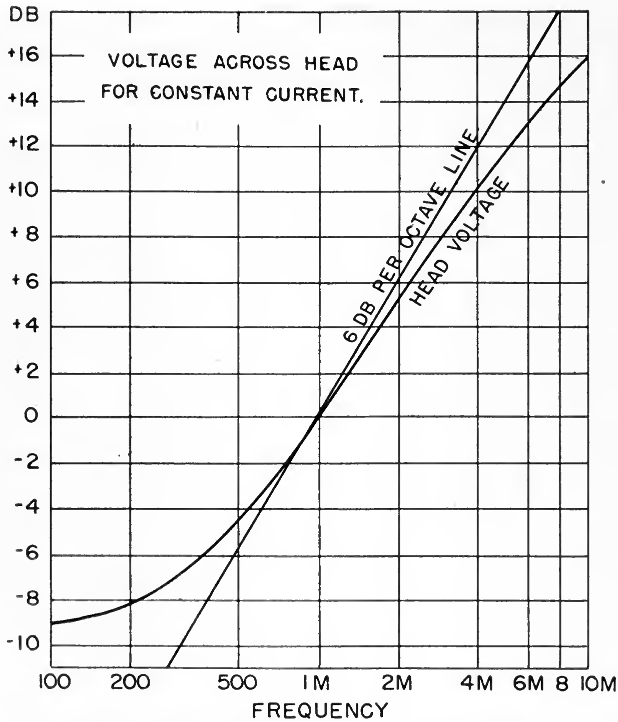


Fig. 8. Record-head frequency characteristic.

The record head is enclosed in a shield and the lead wires from it are tightly twisted. Additional shielding is used on the input transformer and this is mounted in back of the sound head and separated from the amplifier by properly placed shields. A signal-to-noise ratio of over 40 db is obtained, comparing a fully recorded to an erased track.

Frequency Response

The overall frequency-response curves are shown in Fig. 7. These were obtained by recording from an audio oscillator with a constant-voltage input at the microphone socket and measuring the output on playback across a dummy load resistor connected at the speaker socket.

The overall characteristics of the magnetic sound shown in Fig. 7 are determined by the frequency response of the amplifier for both recording and playing back. The results of tests indicate the desirability of recording with nearly constant current in the recording head over the frequency range. The mu-metal recording head exhibits losses at the high frequencies, however, that require compensation in the amplifier. In Fig. 8 will be seen a curve of the voltage across the head throughout the frequency range when it is supplied constant current by means of a series resistor. The departure from a straight line indicates these losses and they are compensated for by raising the amplifier gain the appropriate amount in this region. Actually it has been found desirable to provide a small additional rise at both the high and low frequencies, as this reduces the compensation necessary on playback. The result is less hiss and hum. If these rises are too great, however, there will be a tendency to over-record, with resulting distortion on playback. The departure from the straight line at the low-frequency end of the curve is caused by resistance in the head winding, which remains nearly constant while the reactance decreases as the frequency is reduced. The response of the amplifier on playback relative to 1000 cycles shows a rise of 15 db at 100 cycles and a drop of 1 db at 7000 cycles.

One of the important problems concerning magnetic recording is the selection of the electrical frequency-response characteristics for both recording and playing back. Since the two complement each other to produce an overall frequency response, an infinite number of combinations exist and standardization becomes necessary if films recorded on one projector are to be satisfactorily reproduced on a machine of different manufacture. This is a problem that has already caused concern to the manufacturers of tape-recording equipment where wide variations exist in these characteristics.

The work now being done by the Magnetic Recording Subcommittee is therefore important and will ultimately provide a satisfactory solution to this problem of standardization.

Acknowledgments

Assistance in the design of this projector has been given by H. N. Fairbanks, L. T. Askren and A. N. Ringler, along with helpful suggestions by many others.

Discussion

J. G. Frayne (Westrex Corp.): I notice that the author uses the term "optical" throughout the paper to designate the photographic track. There has been a concerted effort in the 35mm field to use the term "photographic" rather than optical and it is therefore a matter of regret that in the 16mm projector field the term optical seems to be widely adopted.

Gordon A. Chambers, Chairman of the Session (Eastman Kodak Co.): It certainly shows that the work of one of the subcommittees of the Society on a glossary of terms is long overdue.

E. W. D'Arcy (De Vry Corp.): I would like to inquire whether you would state what the post-equalization is in your particular projector.

Mr. Rodgers: I did not show any curves for that. That is one of our biggest problems. On this particular projector, the playback electrical characteristic in the amplifier is such that relative to 1000 cycles 100 cycles is raised about 15 db and the 7000-cycle point is down about 1 db.

W. E. Youngs (International Motion Picture Service, U.S. Dept. of State): What provision do you have for a music and sound effects track when an optical track and a magnetic track are being played at the same time?

Mr. Rodgers: That cannot be done on this machine because the input is switched either to the photographic sound record, or to the magnetic. It might be possible to combine the two and I can see where on foreign language prints the sound effects and music could be put on the photographic sound record and then the voice recorded on the magnetic. This would make it possible to change the language without altering the sound effects. Does that answer your question?

Mr. Youngs: Yes, it does. Now, another thing, in a previous paper I think the Film Board of Canada was talking about two languages recorded on two tracks placed side by side on a variable-area or similar system. Have you worked out any separation system on that, for cutting down, say, half the area?

Mr. Rodgers: That can be done, but then it would be necessary to mask off a section of the optical system so as to reproduce only one at a time. That can be done quite easily.

German Test Film

The D. K. G. Test Film No. 4a, produced by the German Motion-Picture Engineering Society in Munich, is intended as a means for making routine listening and viewing tests in the theater and for checking projector performance. No additional equipment, other than a stopwatch, is required.

Contents

The film consists of a number of tests whose nature is indicated by subtitles as follows:

Clock Ticks. The volume control should be set so that the ticking is just audible and not changed again for the duration of the test.

Projection Rate. A stopwatch is shown running for one minute. Running time should be checked against another stopwatch and the result compared with Table I. Variations from the normal may indicate that adjustments to the film-drive mechanism are necessary.

Picture Placement. This test consists of five concentric lines placed parallel to the edges of the picture, at intervals equal to 1% of standard picture size (Fig. 1). Discrepancies up to 5% of standard picture size can thus be detected. In the center of the vertical and horizontal lines are stepped wedges which will indicate jump and weave in percent.

D. K. G.-Prüffilm Nr. 4a produced by Deutsche Kinotechnische Gesellschaft E.V., München 2, Thorwaldsenstrasse 9/11, Germany.

Test for Travel Ghost. Heavy horizontal lines with crossbars and lettering in the center of the frame permit observation to determine whether the shutter is correctly adjusted (Fig. 2). Should the shutter be in need of adjustment the lines will appear to be distorted vertically and blurred.

Table I.

Normal time in sec	Time shown on film in sec	Frames/sec	
60	50	28.8	fast
60	52	27.7	"
60	54	26.7	"
60	56	25.7	"
60	58	24.8	"
60	**60**	**24**	**normal**
60	62	23.2	slow
60	64	22.5	"
60	66	21.8	"
60	68	21.2	"
60	70	20.6	"

Resolution. A concentric grid fills the entire picture, with numbered axes and diagnals, a central star and four surrounding stars (Fig. 3). The surrounding stars should be in almost as sharp focus as the central star.

Typical Scene. This picture is intended to serve as a general test for screen brightness and quality of reproduction.

During the projection rate test, following some recorded speech, three piano chords are struck as a test of flutter. Both speech and music should be clear and free from distortion.

Figure 1

Figure 2

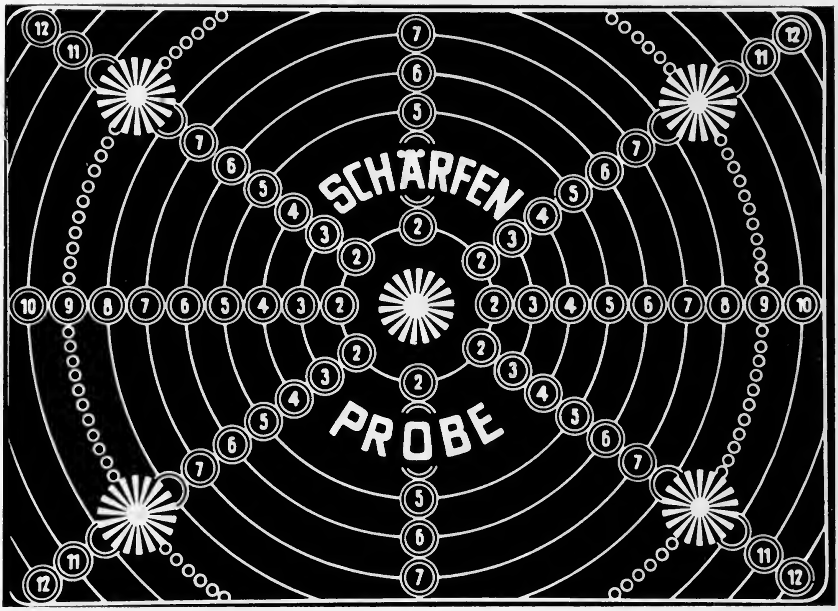


Figure 3

Two Revised American Standards

PH22.43, -.44—16 mm Sound Test Films

Revisions of two American Standards on 16mm sound test films have been approved by the American Standards Association and are published on the following pages.

In accord with the periodic review procedures of the ASA, these two standards were reviewed by the SMPTE Sound Committee in March 1951. No fundamental changes were proposed. There is a minor revision of the section "Resistance to Shrinkage." This revision generalizes the method of measuring shrinkage whereas a particular (and now outmoded) method of the National Bureau of Standards was specified previously. In addition, the titles of the Standards have been simplified and made consistent with current practice.—*Henry Kogel*, Staff Engineer

AMERICAN STANDARD

16mm 3000-Cycle Flutter Test Film

ASA
Reg. U.S. Pat. Office

PH22.43-1953

(Revision of Z22.43-1946)

*UDC 778.55

1. Scope and Purpose

1.1 This specification describes a 3000-cycle sound test film for use in determining the presence of flutter in 16mm sound motion-picture projectors.

2. Test Film

2.1 Recording. The test film shall have either an originally recorded, direct-playback positive variable-area sound track or an originally recorded variable-density sound track developed as a toe record. The recorded frequency shall be within ± 25 cycles of the nominal 3000-cycle frequency. The modulation of the recording shall be 80 ± 5%. The output level of the film shall be constant within ± 0.25 db. (This is equivalent to an amplitude tolerance of ± 0.0015 inch when recording variable-area sound track with a nominal amplitude of 0.055 inch.) The recording shall be accomplished in a recorder so constructed as to keep the flutter content to the absolute minimum consistent with the state of the art. The total rms flutter content of the film shall be less than 0.1% upon shipment by the test film manufacturer. The waveform distortion of the recording shall not exceed 5%.

2.2 Film Stock. The film stock used for the test film shall be cut and perforated in accordance with the American Standard Cutting and Perforating Dimensions for 16-Millimeter Sound Motion Picture Negative and Positive Raw Stock, Z22.12-1947, or the latest revision thereof approved by the American Standards Association, Incorporated.

2.2.1 Resistance to Shrinkage. The film stock used for the test film shall have a maximum lengthwise shrinkage of 0.50% when tested as follows: At least 20 strips of film approximately 31 inches in length shall be cut for measurement of shrinkage. After normal development and drying (not over + 80 F (+ 26.7 C)), the strips shall be placed at least ¼ inch apart in racks and kept for 7 days in an oven maintained at + 120 F (+ 49 C) and a relative humidity of 20%. The strips shall then be removed, reconditioned thoroughly to 50% relative humidity at + 70 F (+ 21.1 C), and the shrinkage measured by a suitable method. The percent shrinkage shall then be calculated on the basis of deviation from the nominal dimension for the length of 100 consecutive perforation intervals given in American Standard Z22.12-1947, or the latest revision thereof.

2.3 Standard Length of Film. The standard length of the flutter test film shall be 380 ft.

2.4 Leader and Trailer. Each test film shall be furnished with a suitable leader, title and trailer.

Note: A test film in accordance with this standard is available from the Society of Motion Picture and Television Engineers.

Approved October 26, 1953, by the American Standards Association, Incorporated

Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
ASA½M1053

Price, 25 Cents

AMERICAN STANDARD

16mm Multifrequency Test Film

ASA
Reg. U.S. Pat. Office
PH22.44-1953
(Revision of Z22.44-1946)
*UDC 778.55

1. Scope and Purpose

1.1 This standard describes a multifrequency sound test film used for testing and adjusting the sound systems of 16mm sound motion-picture projection equipment. The test frequencies on this film are adequate for normal field and general laboratory use.

2. Test Film

2.1 Frequencies. The test film shall contain the following series of frequencies, each preceded by spoken announcement recorded at approximately 10 db below full modulation:

Frequency, cycles	Tone Footage, feet	Frequency, cycles	Tone Footage, feet
400	12	2000	6
50	6	3000	6
100	6	4000	6
200	6	5000	6
300	6	6000	6
500	6	7000	6
1000	6	400	12

2.1.1 Frequency Tolerance. The frequency tolerance of the recorded signals shall be ± 2% of the nominal frequency of each portion of the test track.

2.2 Recording. The test film shall be an originally recorded, splice-free, direct playback, positive variable-area sound track, recorded so that the modulated light is substantially constant when the film is reproduced with a scanning beam of negligible width. Modulation of the recording shall be 95 ± 5% at 7000 cycles. The level within any one frequency of each reel shall be constant to within ± 0.5 db. The recording shall be accomplished on a recorder so constructed as to keep the flutter content of the film to the absolute minimum consistent with the state of the art. The distortion of the recorded wave, up to a frequency of 3000 cycles, shall not exceed 5%.

2.3 Film Stock. The film stock used for the test film shall be cut and perforated in accordance with the American Standard Cutting and Perforating Dimensions for 16-Millimeter Sound Motion Picture Negative and Positive Raw Stock, Z22.12-1947, or the latest revision thereof approved by the American Standards Association, Incorporated.

2.3.1 Resistance to Shrinkage. The film stock used for the test film shall have a maximum lengthwise shrinkage of 0.50% when tested as follows: At least 20 strips of film approximately 31 inches in length shall be cut for measurement of shrinkage. After normal development and drying (not over + 80 F (+ 26.7 C)), the strips shall be placed at least ¼ inch apart in racks and kept for 7 days in an oven maintained at + 120 F (+ 49 C) and a relative humidity of 20%. The strips shall then be removed, reconditioned thoroughly to 50% relative humidity at + 70 F (+ 21.1 C), and the shrinkage measured by a suitable method. The percent shrinkage shall then be calculated on the basis of deviation from the nominal dimension for the length of 100 consecutive perforation intervals given in American Standard Z22.12-1947, or the latest revision thereof.

2.4 Film Identification. Each test film shall be provided with a suitable leader, title and trailer, and shall be accompanied by a calibration of the level of the frequency recordings.

2.4.1 Calibration. The calibration shall be in terms of light modulation at the photocell with a scanning beam of negligible width, and shall be correct to within ± 0.25 db up to and including 3000 cycles, and within ± 0.5 db above 3000 cycles up to and including 7000 cycles. The correction for each frequency shall be so stated that it will give the true level when the correction is added algebraically to the output level measured using the film.

Note: A test film in accordance with this standard is available from the Society of Motion Picture and Television Engineers.

Approved October 26, 1953, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers

*Universal Decimal Classification

Printed in U.S.A.
ASA½M1053

Price, 25 Cents

75th Convention Plans

Nearly two years ago the Board of Governors appointed a special committee under John G. Frayne, to make the 75th a special milestone convention. The first meeting of this committee was held during the Chicago Convention; subsequent meetings and correspondence have enabled Chairman Frayne to submit for the forthcoming Washington Convention the following roster of papers which will consider the developments of facets of the industry and will also be basic and tutorial in nature:

"Black-and-White Cinematography" — C. E. K. Mees, Eastman Kodak Co.
"Color Cinematography" — Gerald F. Rackett, Columbia Pictures Corp.
"Sound" — E. W. Kellogg, RCA Victor Div. (Ret.)
"Professional 35mm Camera" — C. E. Phillimore, Bell & Howell
"16mm Projector and Camera" — M. G. Townsley, Bell & Howell
"Evolution of Motion-Picture Techniques" — James Card, Eastman House
"Motion-Picture Lighting" — Charles Handley, National Carbon Co.
"35mm Projector" — R. Mathews, Los Angeles County Museum; and Willy Borberg, General Precision Laboratory
"Mechanical Television" — J. V. L. Hogan, Consultant
"Electronic Television" — A. G. Jensen, Bell Telephone Laboratories
"The Motion-Picture Laboratory" — John I. Crabtree, Eastman Kodak Co.
"The Evolution of Motion-Picture Theaters" — Ben Schlanger, Theater Consultant

There will be a few additions to this list — but generally this is the frame of the 75th Program.

The papers listed above will be substantial papers of about an hour's length. To these will be added briefer papers about current developments in the industry. These papers are now being sought and arranged by the Papers Committee listed below. If you have a prospective paper or know about one, bring it to the attention of the Committee member nearest you.

W. H. Rivers, *Chairman*, Eastman Kodak Co., 342 Madison Ave., New York 17, N. Y.
Joseph E. Aiken, *Program Chairman*, 116 N. Galveston St., Arlington 8, Va.
Skipwith W. Athey, *Vice-Chairman*, General Precision Laboratory, 16 South Moger Ave., Mt. Kisco, N. Y.
C. E. Heppberger, *Vice-Chairman*, 231 N. Mill St., Naperville, Ill.
G. G. Graham, *Vice-Chairman*, National Film Board of Canada, John St., Ottawa, Canada
Ralph E. Lovell, *Vice-Chairman*, National Broadcasting Co., Sunset and Vine, Hollywood 28, Calif.
John H. Waddell, *Vice-Chairman*, Wollensak Optical Co., 850 Hudson Ave., Rochester 21, N.Y.

Papers Committee Members

James A. Anderson, Alexander Film Co., Alexander Film Bldg., Colorado Springs, Colo.
Mark Armistead, 1041 N. Formosa Ave., Hollywood 46, Calif.
D. Max Beard, Naval Ordnance Laboratory, White Oak, Silver Spring, Md.
Edward E. Bickel, Simpson Optical Manufacturing Co., 3208 W. Carroll Ave., Chicago 24, Ill.
Richard Blount, General Electric Co., Nela Park, Cleveland, Ohio
R. P. Burns, Balaban & Katz, Great States Theaters, 177 N. State St., Chicago 1.
Merle H. Chamberlin, Metro-Goldwyn-Mayer Studios, 10202 Washington Blvd., Culver City, Calif.
P. M. Cowett, Dept. of the Navy, Bureau of Ships, Washington 25, D.C.
E. W. D'Arcy, De Vry Corp., 1111 W. Armitage Ave., Chicago 14, Ill.
W. H. Deacy, Jr., 231 E. 76 St., New York 21, N.Y.
W. P. Dutton, 732 N. Edison St., Arlington 3, Va.
Barry T. Eddy, 10569 Selkirk Lane, Los Angeles, Calif.
Carlos H. Elmer, 410B Forrestal St., China Lake, Calif.

Karl Freund, 15024 Devonshire St., San Fernando, Calif.

Jack R. Glass, 10858 Wagner St., Culver City, Calif.

R. N. Harmon, Westinghouse Radio Stations, Inc., 1625 K St., N.W., Washington, D.C.

Scott Helt, Allen B. Du Mont Laboratories, Inc., 2 Main Ave., Passaic, N.J.

S. Eric Howse, 2000 West Mountain St., Glendale 1, Calif.

L. Hughes, Hughes Sound Films, 1200 Grant St., Denver, Colo.

P. A. Jacobsen, Campus Studios, 100 Meany Hall, University of Washington, Seattle, Wash.

William Kelley, Motion Picture Research Council, 1421 N. Western Ave., Hollywood 27, Calif.

George Lewin, Signal Corps Pictorial Center, 25-11—35 St., Long Island City 1, N.Y.

Glenn E. Matthews, Research Laboratory, Eastman Kodak Co., Rochester 10, N.Y.

Pierre Mertz, Bell Telephone Laboratories, Inc., 463 West St., New York 14.

Harry Milholland, Du Mont TV Network, Station WABD, 515 Madison Ave., New York 22.

W. J. Morlock, General Electric Co., Electronics Park, Syracuse, N.Y.

Herbert W. Pangborn, 6512 Orion St., Van Nuys, Calif.

Bernard D. Plakun, General Precision Laboratory, Inc., 63 Bedford Rd., Pleasantville, N.Y.

Carl N. Shipman, 9544 Burma Rd., Rivera, Calif.

S. P. Solow, Consolidated Film Industries, Inc., 959 Seward St., Hollywood 38, Calif.

J. G. Stott, Du-Art Film Laboratories, 245 W. 55 St., New York 19.

W. L. Tesch, Radio Corporation of America, RCA Victor Div., Front & Cooper Sts., Camden, N.J.

Lloyd Thompson, The Calvin Co., 1105 Truman Rd., Kansas City 6, Mo.

M. G. Townsley, Bell & Howell Co., 7100 McCormick Rd., Chicago 45, Ill.

Allan L. Wolff, Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.

Roy L. Wolford, 3434 W. 110th St., Inglewood 2, Calif.

74th Semiannual Convention

The Society's Fall Convention was held at the Statler Hotel, New York, during the week October 5–9. Registration was 632, of which 90 were ladies' registrations.

The following, in addition to respective officers of the Society, were responsible for Convention arrangements:

Program, Skipwith W. Athey

Papers, W. H. Rivers, Joseph E. Aiken, Geo. W. Colburn, G. G. Graham, Charles Jantzen, Ralph E. Lovell and John H. Waddell

Local Arrangements, W. H. Offenhauser, Jr., R. C. Holslag and S. L. Silverman

Hotel Reservations and Transportation, L. E. Jones

Hospitality, Marie Douglass

Luncheon and Banquet, Emerson Yorke, J. B. McCullough and J. G. Stott

Membership and Subscriptions, A. R. Gallo

Motion Pictures, V. J. Gilcher

Projection, William Hecht and Charles Muller

Public Address, George Costello and Dominick Lopez

Publicity, Leonard Bidwell

Registration, J. C. Naughton

Ladies Program, Mrs. Emerson Yorke and Mrs. Herbert Barnett

The motion-picture shorts shown at the beginning of the various sessions included:

Marciano-La Starza Fight, Republic Pictures

SMPTE Roundup, Emerson Yorke Studio

Let's Ask Nostradamus, M-G-M

Illusions Unlimited, National Broadcasting Company

Excerpts from foreign-language training films, Signal Corps Pictorial Center

TV of Tomorrow, M-G-M

Little League World Series, Emerson Yorke Studio

Hurricane Hunters, Paramount

The Nature of Polarized Light, Polaroid Corp.

A is for Atom, General Electric Company

Madeline, Columbia

A complete listing of the sessions and

papers will be published in the December *Journal.* Attendance during technical sessions generally ranged from 85 to 110, with one special high of 255 during the Thursday Evening 3-D Equipment Session.

As principal speaker at the Get-Together Luncheon, Henry J. Taylor, radio commentator, gave a survey of international political developments. President Barnett, in his address, spoke as follows:

Get-Together Luncheon Remarks by President Barnett

". . . Twice each year for the past 37 years, members of the Society and leaders from every branch of our allied industries have met in a national convention that has grown in size from eleven men to the vast registration of the last two conventions. With size has come strength, importance and responsibilities. Each convention has advanced the theory and practice of engineering in motion pictures, high-speed photography, and more recently in television, and the related arts and sciences.

"The practical missions of our conventions are not accomplished by passive attendance. You will not fulfill your duty to yourself, your company, and to our industries solely by listening to informative discussions by authorities in your fields. You must be more than a mental sponge absorbing technical knowledge. This is a market place where the costly lessons of research and experience can be acquired for the price of asking questions. This is a meeting of minds—minds that know and minds that *want* to know. This is a get-together of productive people with ideas and imagination and an insatiable curiosity about the things they suspect lie beyond the horizon.

"In addition to technical benefit to be derived, there are other rewards for your participation in the common cause of a better product. The Society expects each one of you to use this opportunity to strengthen the bonds within the industry. This is the time to renew old acquaintances; to turn business associates from other parts of the country into friends; the chance to meet the men whose names until now were bylines in technical journals.

"In all of these ways you will contribute to the strength and the progress of the motion picture and the television industries. And when the last session ends on Friday, you will leave here enriched in mind and spirit with the knowledge that our engineers have the ability and will to contribute their share in keeping the film industry a vital, dynamic part of the American economy.

"There is one lesson above all others which you should learn this week. You are *never* working alone. Right behind you, ready to help you over the big obstacles, ready to share with you their hard-earned knowledge, are nearly 5,000 engineers and scientists who voluntarily work together as the Society of Motion Picture and Television Engineers. Available to you in the *Journal* and other publications is the most comprehensive source of motion-picture technical information in the world, as well as for certain aspects of television. The potential value of this knowledge to our related industries depends upon the use you make of it and to the degree you contribute to it in recording new discoveries.

"We are now in the most competitive era the motion picture has ever known. Losses of the past few years have been tragic, especially to the small independent exhibitor. Aside from the personal misfortunes this has brought, it is serious to the industry as a whole. We fully realize the small contribution made by community theaters to the total gross boxoffice of any production. There is, on the other hand, a much greater service these houses perform in shaping the movie-going habits of the American audience. This, I think, is a challenging problem deserving of most serious consideration.

"Out of the adversities of the past has come a reawakening which shows promise of restoring motion pictures to an important economic position. This is particularly gratifying to our Society in that the industry has seen the value in drawing on the technical resources long waiting to be used. We are doubly grateful that these resources were available. Whether or not any of these, or all, may show the way back, we know that it is unwise to lapse again into a feeling of false security. As important as the techniques may be which have been introduced over the past year, no industry on earth is rich enough to waste them on selling otherwise unsalable merchandise. Furthermore, the industry cannot expect these devices to carry them forever. Our long range salvation depends on how well we have learned from the past few years and to the degree we apply every segment of the industry to a most thorough study of its needs and responsibilities to the paying audience.

"The engineer has today an excellent opportunity to contribute worthwhile advances to a receptive industry. I am sure you are prepared to meet this challenge."

For the first time since the 68th Convention at Lake Placid, an evening session was given over to the presentation of awards. The record of the citations will be given in the December *Journal.*

The Ladies Program included a visit to the U.N. Headquarters, a special showing of old-time motion pictures at the Museum of Modern Art, and attendance at a performance of *The Robe.*

There were 13 meetings of the various Engineering Committees held during the course of the Convention. Results of such meetings are published from time to time in the *Journal* as reports by committee chairmen and in the Engineering Activities column. At the Papers-Editorial meeting there was detailed discussion about ways to get papers best published in the *Journal* and about Papers Committee operation for the 75th Convention. The latter subject is covered in a separate story in this *Journal.*

Book Review

The Theory of Stereoscopic Transmission and Its Application to the Motion Picture

By Raymond Spottiswoode and Nigel Spottiswoode. Published (1953) by The University of California Press, Berkeley 4, Calif. 200 pp. 32 illus. + 6 pp. 3-D illus. 6 × 9 in. $6.00.

This volume is the first full-scale treatment of the problems of stereoscopic transmission. On this score alone it is a great contribution to the art which should be required reading for the technicians of those producers who have been willing to film and exhibit stereoscopically inferior pictures — which, to date, means substantially all of them.

In order to cast the volume in its proper light, it is necessary to examine its basic philosophy. It tacitly assumes that if two retinal images are produced in the eyes of the observer which exactly reproduce those that would have been received from the original scene, the observer will then interpret them in exactly the same manner. Since the authors are well aware that such reproduction is not completely possible, their procedure is to develop the mathematics of this ideal supposition, analyzing the effects of inevitable departures along the way. The result is a highly formulated mathematical treatment.

The attack is analytical and equational rather than geometric. Of course the equations are derived from the geometry of the situation, but the conclusions are in general extracted from the equations rather than from geometric figures as in many instances they might well have been. Though the procedure renders the results more rigorous, it is somewhat unfortunate for the general reader who usually is not in the habit of tracing through mathematical formulae but can quite readily follow geometric figures because of their greater recognizable visual content. On this score the reader will do well to be constantly aware of the stereoscopic diagrams in anaglyph form enclosed in the back cover. One could have wished, however, for a more liberal use of explanatory figures.

I also find the derivations unnecessarily long, causing the reader to become too immersed in detail. Each derivation need not have been carried through every step. For instance, on p. 24, seven equations are given in order to obtain an equation giving the distance from the observer to the stereoscopic image point. Since the mathematics is a simple similar triangle manipulation, it would seem to me to have been a better procedure simply to state that "from fig. 4 by the use of similar triangles the following equation can be derived," giving only the end result. Such a consistent reduction of the mathematical manipulations throughout the book would have freed the reader to pay more attention to the important results.

Though the authors do an excellent job of calling attention to the limitations of the mathematical approach, I find my own misgivings far exceed theirs. They slip occasionally into translating stereoscopic image formation into spectator interpretation as though the latter inevitably followed. For instance, on p. 34 in discussing the separation of infinity points on the screen the following statement appears: "(2) B zero·N will be zero. Thus points originally at infinity will appear to the spectator at infinity." This implicitly assumes that the spectator interprets what he sees as he should. A more careful statement would have been ". . . Thus points originally at infinity will be viewed with eye axes parallel."

Certainly their treatment is basic and necessary, but the variables are numerous and the psychological factors of such great importance that I feel that the ideal stereoscopic motion picture will only be arrived at through empirical study of audience reactions to controlled alteration of the variables. Thus it is well to know how to produce a stereoscopic image which is theoretically ortho-stereoscopic for a single, centrally located viewer, but such an image in the long run is in itself of no importance. Ultimately we are not interested in reality but in the artistic and aesthetic effect of stereoscopic image patterns on audiences. We are interested in producing a piece of sculpture which has a high artistic impact rather than in reproducing exact forms through technical skill. Thus I doubt very seriously that motion-picture producers will ever make great use of the mathematical approach, but will depend on gradually blocking out in broad terms the areas of operation which minimize eyestrain and maximize favorable audience reaction. This will be achieved by empirical experimentation with image shapes.

On the technical side I feel that the authors make too little distinction between absolute convergence and relative convergence. It seems to me that the evidence is that absolute convergence is of very little importance — that is, the location of a stereoscopic image as a whole, assuming the existence of a completely dark theater where no external reference points exist (an impossibility, of course) does not depend on convergence. However the image is fixed, once it has been fixed, the internal location of points depends to a very high degree on relative convergence and mathematics comes into its own.

The importance of this point becomes apparent in considering separations of infinity point-pairs greater than the human interocular. In earlier papers of my own I considered such separations bad practice because I assumed that eyestrain would result. Recent experiments on this point seem to indicate clearly that the eyes can diverge through a small angle (which amounts to a large one from the stereoscopic viewpoint) without eyestrain. By doing so the two retinal images obtained from two pictures on the screen with infinity points separated by six inches are exactly the same as they would be if the pictures were separated by the human interocular and the eye axes remained parallel. The interpretation of the relative positions of internal points will probably be the same in both cases, but where is the image as a whole in the first case? Where is the image as a whole when a stereo pair placed side by side in a book is fused by divergence without the aid of lenses or filters?

In spite of the fact that theater reference points or screen texture are always present, the location of images as a whole seems to me to depend much more heavily on psychological factors than do the relationships of internal points.

The above is not meant as a criticism of this excellent and much needed volume but only as a word of caution on the way. We know very, very little about the interpretive mechanisms of vision. The worker in this field should consider this volume a real "must" but should always maintain a wholesome, objective doubt of all reasoned, calculated results unless there is conclusive evidence that they have been empirically verified by a number of observers.

Outside of the mathematical passages, the writing is unfortunately not as clear or precise as it might be. Also, in their efforts to cover every phase of stereoscopic transmission, the authors often give almost equal emphasis to trivia and fundamentals, so that a reader could get a discouraging impression of the complexity of the subject.

On a minor key. The alternate-frame

camera shown in Fig. 22, p. 105, has an error not pointed out by the authors. The path of the right-eye picture is longer than that of the left eye by a distance of *tc*, say 2½ in. Thus a similar double-lens camera would have one lens 2½ in. in back of the other—a bad situation for close objects.

Unfortunately the printing is quite inferior. The letter separation within a single word is sometimes irregular to the point of having the appearance of two words.

The authors are to be congratulated for the completeness of the book. They have ferreted out many obscure points that have never before reached the literature. Certainly no one else has approached the field with their degree of thoroughness.—*John T. Rule,* Massachusetts Institute of Technology, Cambridge 39, Mass.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 Membership Directory.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Moore, James Whitney, Editor, Movie Makers, Managing Director, Amateur Cinema League, Inc., 420 Lexington Ave., New York 17, N.Y. (A)

Neilis, Frank A., Jr., Television Projectionist, Du Mont Television Network. **Mail:** 3914 Avenue I, Brooklyn 10, N.Y. (A)

Norman, Harry H., Mechanical Engineer, Zig Zag Machine Co. **Mail:** 15235 Valley Vista Blvd., Sherman Oaks, Calif. (A)

Nosti, Benigno, Head, Film Dept., Circuito CMQ, S.A., M St. #312, Vedado, Havana, Cuba. (A)

O'Donnell, William C., Sales, Kollmorgen Optical Corp., 347 King St., Northampton, Mass. (A)

Ostrowski, Wallace W., Film Technician, Color Corporation of America. **Mail:** 244 North California St., Burbank, Calif. (A)

Palmer, Merrill A., Project Photographer and Recorder, Lovelace Foundation for Medical Education and Research. **Mail:** 2312 Rice Ave., N.W., Albuquerque, N.M. (A)

Pasqualetti, Bev J., Instructor, In Charge, Dept. of Photography, City College of San Francisco. **Mail:** 78 San Jacinto Way, San Francisco 27, Calif. (A)

Patton, Billy L., Electrical Engineer, WJAR-TV. **Mail:** 58 Merritt Rd., Riverside, R.I. (A)

Pennington, Harry, Jr., Television Films. **Mail:** 134 East Agarita St., San Antonio 12, Tex. (M)

Petito, Vincent Arthur, Motion-Picture Equipment Repair, U.S. Army Signal Corp. **Mail:** 171 Nostrand Ave., Brooklyn 5, N.Y. (M)

Reitz, Lewis P., Jr., Electrical Engineer, Hughes Aircraft Co. **Mail:** 700 Mexico Pl., Palos Verdes Estates, Calif. (M)

Rodgers, John A., Electrical Engineer, Camera Works, Eastman Kodak Co., 333 State St., Rochester 4, N.Y. (M)

Rose, Ernest D., Film Producer, Owner, Trans-Lingual International Film Service, Eagle-Lion Studios, Hollywood 46, Calif. (A)

Ruark, Henry C., Jr., Professor, c/o Audio-Visual Center, Indiana University, Bloomington, Ind. (A)

Salerno, Anthony, Photographic Chemist, Pavelle Color, Inc. **Mail:** 104–69—48 Ave., Corona, N.Y. (M)

Schardin, Hubert, Scientific Director, Laboratorie de Recherches; Professor, University of Freiburg. **Mail:** Rosenstrasse 10, Weil am Rhein, Baden, Germany. (M)

Schober, Edwin E., Still and Motion-Picture Photographer, Fresno Bee. **Mail:** 324 North Fresno, Fresno, Calif. (A)

Schweiger, Arthur F., Maintenance Engineer (Audio and Video), National Broadcasting Co. **Mail:** 135 Sylvia La., New Hyde Park, Long Island, N.Y. (M)

Serbolov, Vladimiro de Berner, Supervisor, Engineer, Deksa, S.A. **Mail:** Av. Veracruz #73, Mexico 11, D.F., Mexico. (A)

Shurcliff, William A., Physicist, Polaroid Corp. **Mail:** 19 Appleton St., Cambridge, Mass. (M)

Siegel, Burt, Film Technician, Cameraman, Editor. **Mail:** 5240 Broadway, New York, N.Y. (A)

Smith, Lloyd A., Executive, Eastman Kodak Co., Kodak Park, Rochester, N.Y. (M)

Smoot, M. Graham, Coordinator, Visual Health Education, Texas State Department of Health, 410 East Fifth St., Austin, Tex. (M)

Spinrad, Leonard, Consultant on Motion Pictures, 511 E. 20 St., New York 10, N.Y. (M)

Steglich, Kurt, Mathematician, Askania-Werke AG, Bundesallee 86–89, Berlin-Friedenau, Germany. (M)

Steuer, Walter, Mechanical Engineer, Vice-President, Zoomar, Inc., 55 Sea Cliff Ave., Glen Cove, Long Island, N.Y. (M)

Stork, John, Project Engineer, Altec Lansing Corp., 9356 Santa Monica Blvd., Beverly Hills, Calif. (M)

Stuart, A. J., Jr., Motion-Picture Engineer, Baptist Foreign Mission Board, 2037 Monument Ave., Richmond, Va. (A)

Stuart, James Leslie, Chief Engineer, George Humphries & Co., Ltd., 71 Whitfield St., London, England. (A)

Surette, William E., Jr., Development Engineer, Synthetic Vision Corp. **Mail:** 821 Valley St., Dayton 4, Ohio. (A)

Taylor, Herbert B., Transmission Engineer, Walt Disney Productions. **Mail:** 1520 Bel Aire Dr., Glendale 1, Calif. (A)

Thomasson, Frank, Sound Engineer, Rowley United Theatres, Inc., 314 South Harwood, Dallas, Tex. (A)

Tottenhoff, John P., Salesman, Watland. **Mail:** 930 South Lincoln, Park Ridge, Ill. (A)

Townsend, James Harvey, Jr., Vice-President and Chief Engineer, Unifilms, Inc., 146 E. 47 St., New York, N.Y. (M)

Traub, Alan C., Research Physicist, American Optical Co., Southbridge, Mass. (A)

Tucker, Guillermo, Manager, Radio Caracas TV, Barcenas A Rio, Caracas, Venezuela. (M)

Van Dyke, Willard, Cameraman, Affiliated Film Producers, Inc., 164 E. 38 St., New York 16, N.Y. (A)

Watson, H., University of California at Los Angeles. **Mail:** 115 Monterey Blvd., Hermosa, Calif. (S)

Wells, Gerald, Sr., Camera and Projector Servicing. **Mail:** 74 East Chalmers Ave., Youngstown, Ohio. (A)

Werner, Friedrich, Physicist, Member, Board of Directors, Askania-Werke, 88 Bundesallee, Berlin-Friedenau, Germany. (M)

Wessel, Karl H., Chief Engineer, Oxford Electric Corp. **Mail:** 4892 North Mason Ave., Chicago 30, Ill. (M)

Westing, John C., Sound Engineer, DeFrenes Co. **Mail:** 21 South Farragut St., Philadelphia 39, Pa. (A)

Westphal, William H., Raw Stock Sales, W. J. German, Inc. **Mail:** 224 Hamilton Rd., Ridgewood, N.J. (M)

Whiteside, Duncan, Director of Radio-TV, University of Mississippi, University, Miss. (A)

Whitley, Eric G., Product Design Engineer, Allen B. DuMont Laboratories, Inc. **Mail:** Apt. 32-G, 160 Gordonhurst Ave., Upper Montclair, N.J. (A)

Widmayer, William L., Assistant Head, Camera Dept., Columbia Pictures Corp. **Mail:** 5340 Teesdale Ave., North Hollywood, Calif. (A)

Wiley, Gerald L., Air Force Motion-Picture Camerman, U.S. Air Force, 1st Photo Squadron, 200 King St., Alexandria, Va. (A)

Williams, John B., Sound and Projection Engineer, Army and Air Force Motion-Picture Service. **Mail:** European Motion-Picture Service, APO 807, U.S. Army, c/o Postmaster, New York, N.Y. (A)

Wilson, Albert, Motion-Picture Director, Signal Corps Pictorial Center. **Mail:** 3086—33 St., Long Island City 2, N.Y. (M)

Woodruff, George N., Physicist, Reaction Motors, Inc., Rockaway, N.J. (M)

Woodruff, Rodger L., Technical Supervisor, KRON-TV, 901 Mission St., San Francisco, Calif. (M)

Yearwood, Taylor C., Projectionist, Wometco Theatres. **Mail:** 6401 N.W. Miami Pl., Miami 38, Fla. (A)

Young, Jerry O. W., Sales Engineer, Worsco Audio Dept., Sound Engineer, Snazelle Studio. **Mail:** 1420 Pacific Ave., San Francisco, Calif. (A)

Ziller, Robert, Student, Projectionist, Fox Theatre. **Mail:** 1037 North 31 St., Billings, Mont. (A)

Zuidema, John W., Product Engineer, Film Testing, Eastman Kodak Co. **Mail:** 465 Colebrook Dr., Rochester 17, N.Y. (A)

CHANGES IN GRADE

Badmaieff, Alexis, (A) to (M)
Bennett, Norman, (S) to (A)
Blaskiewicz, John V., (S) to (A)
Chamberlin, Merle H., (M) to (F)
Dearing, L. M., (M) to (F)
Drew, Russell O., (M) to (F)
Elmer, Carlos H., (M) to (F)
Fogelman, Ted, (A) to (M)
Gardenhire, Hervey, (A) to (M)
Gillette, Frank N., (M) to (F)
Graham, Gerald G., (M) to (F)
Groves, George R., (A) to (M)
Hallows, Raymond L., Jr., (S) to (A)
Halprin, Sol, (M) to (F)
Lazell, Robert C., (S) to (A)
Loughren, Arthur V., (M) to (F)
Lovell, Ralph E., (M) to (F)
Miller, Arthur J., (M) to (F)
Mosser, Adrian T., (S) to (A)
Nuttall, Howard T., (A) to (M)
Servies, John W., (M) to (F)
Soltys, Richard J., (S) to (A)
Spottiswoode, Raymond J., (M) to (F)
Townsend, Charles L., (M) to (F)
Veal, T. G., (M) to (F)

DECEASED

McInnes, Harold W., 6560 East Hastings St., North Burnaby, British Columbia. (A)

Rodrigues, R. T., Manager, Kodak, Ltd. **Mail:** Rua Garrett 33, Libson, Portugal. (M)

New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.

This film reader has been designed with a $10\frac{1}{2} \times 10$ in. screen. It is a portable table model with the film carriage located near table level to minimize the operator's fatigue. Interchangeable lenses provide magnifications of $7\frac{1}{2}$ to 14, with other magnifications available by special order. There are interchangeable 35 mm and 16 mm film carriages. Special carriages to suit comparator work and other applications are available from D-H Instrument Co., P.O. Box 205, Station A, Palo Alto, Calif.

A new series of *f*/1.8 Super-Cinephor projection lenses designed to produce maximum brightness, contrast and sharpness, edge-to-edge, on all types of professional motion-picture screens is announced by the Bausch & Lomb Optical Co., Rochester 4, N.Y. These lenses are intended to lessen the problem of resolution at the outer margins of the screen and to increase the illumination, distributing it evenly.

These new lenses employ five different types of glass, two of which are varieties of extra dense barium crown glass, recently put on a production basis in the Bausch & Lomb glass plant. They are said to combine the optical advantages of both flint and older types of crown glass, without the disadvantages of either, and are designed to eliminate color absorption and transmit the full color and brightness of the image.

SMPTE Lapel Pins

The Society has available for mailing its gold and blue enamel lapel pin, with a screw back. The pin is a $\frac{1}{2}$-in. reproduction of the Society symbol — the film, sprocket and television tube — which appears on the *Journal* cover. The price of the pin is $4.00, including Federal Tax; in New York City, add 3% sales tax.

Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, at no charge to the member. The Society's address cannot be used for replies.

Position Available

Technical Photographer, age 27 to 38, for senior position with large California industrial research organization. Should be conversant with contemporary techniques for recording data; acquainted with microscopy, graphic arts and color processes. Job involves application of photographic techniques as experimental tool in research projects. Administrative experience helpful. Excellent career opportunity for an ingenious and inventive person. Retirement pension and other benefit plans. Application held in strict confidence. Write giving personal data, education and experience to Henry Helbig and Associates, Placement Consultants, Examiner Bldg., 3d and Market Sts., San Francisco 3, Calif.

Position Wanted

Engineer, B.M.E.: Creative designs, product improvement. Photographic and electronic-mechanical fields. Cameras (film, image-orthicon and iconoscope TV cameras), color film processing, production tooling, radar. Simple constructions, pleasing appearance. Special product or production blueprints. Write J. Rafalow, Selden, N.Y.

Meetings

The American Society of Mechanical Engineers, Annual Meeting, Nov. 29–Dec. 4 Statler Hotel, N.Y.

Society of Motion Picture and Television Engineers, Central Section Meeting, Dec. 10 (tentative), Chicago, Ill.

American Institute of Chemical Engineers, Annual Meeting, Dec. 13–16, St. Louis, Mo.

American Institute of Electrical Engineers, Winter General Meeting, Jan. 18–22, 1954, New York

National Electrical Manufacturers Assn., Mar. 8–11, 1954, Edgewater Beach Hotel, Chicago, Ill.

Radio Engineering Show and I.R.E. National Convention, Mar. 22–25, 1954, Hotel Waldorf Astoria, New York

Optical Society of America, Mar. 25–27, 1954, New York

75th Semiannual Convention of the SMPTE, May 3–7, 1954, Hotel Statler, Washington

American Institute of Electrical Engineers, Summer General Meeting, June 21–25, 1954, Los Angeles, Calif.

Acoustical Society of America, June 22–26, 1954, Hotel Statler, New York

Photographic Society of America, Annual Meeting, Oct. 5–9, 1954, Drake Hotel, Chicago, Ill.

76th Semiannual Convention of the SMPTE, Oct. 18–22, 1954 (next year), Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955, Drake Hotel, Chicago

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955, Lake Placid Club, Essex County, N.Y.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal*.

Improved Color Films for Color Motion-Picture Production

By W. T. HANSON, JR., and W. I. KISNER

Negative and positive color films have been made available to the industry in recent years. Several systems are possible for inclusion of special effects when using materials of this type, but the preferred system appears to be that using black-and-white separation positives and a color internegative. Four materials are described which can be used in a system of this type or which can be used in conjunction with existing commercial color motion-picture production processes. Three of these materials represent improvements over earlier products of a similar type which were used in the last few years for a number of motion-picture productions. Formulas and procedures for use with these new films are given and some of the problems associated with printing, process adjustment and control are discussed.

Contents

Presented on April 30, 1953, at the Society's Convention at Los Angeles by W. T. Hanson, Jr., Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y., and W. I. Kisner (who read the paper), Motion Picture Film Dept., Eastman Kodak Co., 343 State St., Rochester 4, N.Y. (This paper was received October 19, 1953.)

I. Introduction

During the past few years, a number of negative and positive color films have been made available to the motion-picture industry. Fully appreciative of the flexibility offered by a negative-positive system from long experience in production of black-and-white pictures, the industry quickly sought ways to utilize these new materials. Some laboratories incorporated the new materials into their existing color processes while others were able to use them in systems of their own design.

In selecting a system for producing color motion pictures, it is well recognized, as in black-and-white work, that it is necessary to employ intermediate steps between the original camera film and the final release print film in order to incorporate the various effects so essential to a finished production. Such steps are also desirable, even when no effects are to be included, to protect the original against possible damage. When the original camera film is an integral-tripack color negative material, there are several possible systems which might be employed. These systems are shown diagrammatically in Figs. 1A through 1D.

The scheme shown in Fig. 1A employs black-and-white films for both positive and negative intermediate stages. The systems shown in Figs. 1B and 1C employ black-and-white materials for only one of the intermediate stages and a color material of the integral-tripack type for the other intermediate stage. In the method shown in Fig. 1D, two color materials of the integral-tripack type are used for the intermediate steps.

While many factors both of technical and economic nature must be considered in choosing a system for production use, there are certain obvious objections to three of the systems shown. The system shown in Fig. 1A is too cumbersome for production use because of the necessity for printing twice from separations. The system shown in Fig. 1B is also unsuitable because of the necessity for making the release prints from separation negatives. The system shown in Fig. 1D has the disadvantage that no protection is provided against loss of the color original or intermediates due to

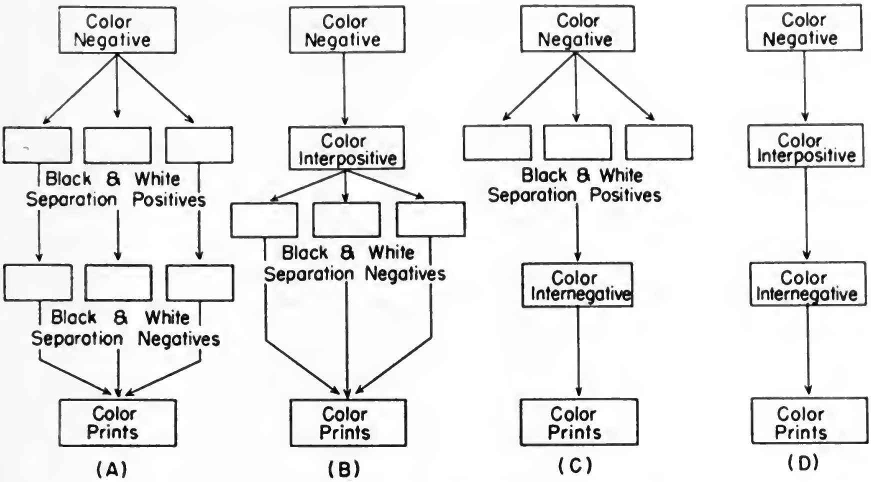


Fig. 1. Systems of color motion-picture production.

possible change of the dye images. Separation positives or negatives would have to be made if such protection were desired. In addition, it is unlikely that adequate reproduction quality could be obtained with such a system at the present time.

The system shown in Fig. 1C overcomes the objections cited for the other systems and appears to be the best suited to production work. Materials suitable for a system of this type are described in this paper.

In 1950, the Eastman Kodak Company provided the industry with a color negative material (Eastman Color Negative Film, Type 5247) and a color print material (Eastman Color Print Film, Type 5381).[1] These films were used together or separately in various commercial processes for production work. In 1951, Eastman Panchromatic Separation Film, Type 5216, and Eastman Color Internegative Film, Type 5243, were introduced.[2] A series of films was then available which could be used together in a system such as that shown in Fig. 1C or which could be used in conjunction with existing commercial color motion-picture production processes. Since that time, numerous color motion-picture productions have been made utilizing one or more of these materials. They have also found extensive use in the preparation of slidefilms and film strips for commercial and educational purposes.

An ever-increasing need has been felt for a color negative material which was sufficiently sensitive and which was correctly balanced for use in the studio with tungsten illumination without the use of filters. Early development work on a product of this type soon indicated that changes could also be made in the characteristics of the color internegative and print films which would result in improved print quality. As a result of this program, three new films have now been made available and appropriate changes have been made in the techniques for handling them to accomplish the desired aims. It is the purpose of this paper to describe these new films, to discuss procedures for exposing and processing them and to indicate some of the problems which may be encountered in their use.

II. Eastman Color Negative Safety Film, Type 5248

General Description

The new color negative film is known as Eastman Color Negative Safety Film, Type 5248. It is a 35mm integral-tripack, incorporated-coupler type film similar in structure to the previous Type 5247 Film, but balanced for use with tungsten (approximately 3200 K), rather than for daylight illumination. It can, of course, be used under daylight conditions or carbon-arc lighting with suitable filters.

The structure of the film is shown in Plate I. It is composed essentially of three emulsions sensitive to blue, green and red light, respectively, and coated on a single safety film support. Between the blue- and green-sensitive layers is a yellow filter layer which prevents blue light from reaching the bottom two emulsion layers, which are also blue-sensitive. The emulsion layers contain dye couplers dispersed within them so that, after exposure and processing, metallic silver and appropriate dye images are produced in each layer. The silver is later removed from the film, leaving the dye images.

As in the case of the earlier Type 5247 Film, two of the couplers dispersed within the emulsion layers are themselves colored. The original color is discharged in proportion to the amount of image dye formed, and the remaining colored coupler serves as a mask to provide correction for unwanted absorption in the process dyes. The characteristics of these colored couplers are similar to those which have been described in previous papers.[1,3]

After processing, the color negative appears as shown in Plate II. Each area of the color negative is complementary in color to the corresponding area in the original scene and, as with other types of negatives, the light and dark tones of the negative are reversed with respect to those of the original subject. In addition to these characteristics, a prominent orange color is observed in all areas of the negative which have received little or no exposure, because of the color-correcting mask remaining in the emulsions.

Characteristics

Eastman Color Negative Film, Type 5248, is balanced for use with 3200 K tungsten illumination. Under these conditions, its speed is slightly less than that of Eastman Background-X Panchromatic Negative Film, Type 5230. Its contrast characteristics are suitable for use with the other materials discussed in this paper. The film is also adaptable for use with color systems employing other films and techniques than those described here. The exposure latitude is somewhat greater than that found for reversal color films. The graininess characteristics of Type 5248 Film are slightly better than those of the earlier Type 5247 Film. The correction for blue-light absorption provided by the colored couplers has also been modified so that blue subjects are not rendered abnormally bright in the reproduction, as was the case with the earlier film. This results in a lower blue-light density for the processed film.

The individual emulsion layers of Eastman Color Negative Film, Type 5248, have keeping properties similar to those of black-and-white negative materials. However, in the case of integral-tripack color films the requirement of maintaining the original color balance must be fulfilled. The storage conditions are therefore slightly more critical than those used for black-and-white negative materials. For extended periods of storage, the film should be kept at temperatures not exceeding 55 F in order to minimize color-balance changes. Regulation of humidity is not important as long as the film remains in the unopened, original, taped can. Ample

Table I. Filters Required With Various Light Sources for Exposure of Eastman Color Negative Film, Type 5248.

Light source	Light source* filter required	Camera filter* required
3200 K Tungsten lamps or "CP" lamps (approx. 3350 K)	None	None
Daylight (sunlight plus some skylight)	None	Kodak Wratten No. 85
M-R Type 170, 150-amp, high-intensity arc	Straw-colored gelatin filter such as Brigham Y-1	Kodak Wratten No. 85
M-R Type 40, 40-amp Duarc	Florentine Glass	Kodak Wratten No. 85

* These are approximate corrections only, since final color-balancing will be done in printing.

time should be allowed for the film to come to equilibrium with the room conditions when the film is removed from storage, and before the tape is removed from the can, in order to prevent condensation of moisture from the atmosphere on the cold film. For a single 1000-ft, 35mm roll, this would generally require about four hours.

Each of the emulsion layers has latent-image keeping properties similar to those found for black-and-white negative films. However, as is the case with emulsion keeping before exposure, the problem is more serious with color films because changes may occur in the exposed film, particularly under storage conditions of high temperature and/or humidity which will result in changes in color balance. It is possible too, that under adverse conditions, the emulsion layers may be affected by the antihalation backing, giving rise to a mottle which will print through to the positive. It is desirable to process the negative film as soon as possible after exposure.

Exposure of Film

Eastman Color Negative Film, Type 5248, is furnished in standard camera lengths for use in conventional black-and-white cameras. It is provided with American Standard negative-type perforations, but which have a shorter pitch dimension.* Camera magazines are loaded in the same manner as for standard black-and-white negative materials.

The camera should be checked photographically for correct focus before starting any production work, because a camera which has been adjusted to obtain critically sharp focus for black-and-white materials may not be adjusted properly for use with color films.

It should also be noted that different types of antireflection coatings cause variations in the color quality of the light transmitted by various camera lenses. In present-day coatings, color variations are usually held within suitable limits. Some of the earlier types of coatings, however, have caused difficulty. It is a good plan to check all lenses photographically, for any variations of this sort, so that they can be interchanged without fear of color-balance shifts.

When 3200 K tungsten illumination is used, no filter is required on the camera or with the light source. It is also possible to use "CP" lamps (approximately 3350 K), since the slight departure in color temperature of these sources from 3200 K can be compensated for in the

* Proposed American Standard PH22.93, 35mm Motion Picture Short-Pitch Negative Film, *Jour. SMPTE, 59:*527, Dec. 1952.

Table II. Illumination (Incident Light) Table for 3200 K Tungsten or "CP" Lamps for Use With Eastman Color Negative Film, Type 5248.

(Shutter speed approximately 1/50 sec; 24 frames/sec)

Lens apertures.	$f/2.3$	$f/2.8$	$f/3.5$	$f/4.0$	$f/5.6$
Number of foot-candles required .	300	400	600	800	1600

printing operation. The filters required when the film is used with light sources differing considerably in quality from the 3200 K tungsten illumination, are given in Table I.

In lighting a set which is to be photographed on Eastman Color Negative Film, Type 5248, the basic lighting contrast should be fairly soft and the illumination should be distributed evenly. Extremely flat lighting, such as provided by extended front-light sources alone, is undesirable, however, since the results are very uninteresting and lacking in character. Some modeling light can be employed effectively but with lower lighting ratios than those ordinarily used for black-and-white photography. Lighting ratios should not ordinarily be greater than about 3:1, but this will be somewhat dependent upon the range of reflectances encountered in the subject. Where special effects are desired, higher lighting ratios may be used, but experience is required to obtain the exact effect intended.

In addition to the usual footage exposed for the purpose of scene identification (slate shots), it is desirable to expose additional footage to serve as a color-balance reference. It is suggested that a neutral test card or gray scale and suitable color patches be included in the scene. These should be large enough to permit densitometric measurements of the processed negative. This is an invaluable aid in later work involving color-timing and color-printing.

The exposure indexes for use with this film are:

Tungsten – 25 Daylight – 16*

* With Kodak Wratten Filter No. 85.

These values are suitable for use with meters equipped with calculators for ASA Exposure Indexes. The values also apply if the meter reading is taken from a gray card of about 18% reflectance, held close to, and in front of, the subject, facing the camera. For unusually light- or dark-colored subjects, the exposure should be decreased or increased, respectively, from that indicated by the meter. For meters which are equipped for measuring incident light, the data contained in Table II will be useful.

Choice of Costume Colors, Make-Up, Colors for Set Properties, Artwork, etc.

Before starting actual production, it is desirable to make careful tests of various pigments, fabrics, make-up materials, etc., and to determine how these colors will be reproduced in the final print film, using the complete process intended for production. The results of these tests should be evaluated and carefully catalogued for future reference.

Processing

Eastman Color Negative Film, Type 5248, can be processed in conventional-type continuous processing machines, with minor modifications to allow for all of the steps required. The processing steps with approximate times are shown in Table III. The actual processing times will vary somewhat according to the individual processing machine, depending upon the degree of agitation employed, the rate of recirculation, the replenisher rate, etc. The most suitable material for processing machine construction is stainless steel AISI-316. Other materials can, of course, be used for

Table III. Processing Steps for Eastman Color Negative Film, Type 5248.

1.	Prebath	10 sec
2.	Spray rinse	10–20 sec
3.	Color developer	12 min
4.	Spray rinse	10–20 sec
5.	First fixing bath	4 min
6.	Wash	4 min
7.	Bleach	8 min
8.	Wash	8 min
9.	Fix	4 min
10.	Wash	8 min
11.	Wetting agent	5–10 sec
12.	Dry	15–20 min

processing tanks, provided they are lined with hard rubber or lead.

Since the film is sensitive to light of all colors, it must be handled in total darkness through the first fixing or stop bath following color development. The remaining processing operations can be carried out in a lighted room. Where illumination is needed for dials, meters, etc., during color development, a fixture fitted with a Kodak Safelight Filter, Wratten Series 3, may be used, provided such illumination is not incident upon the film itself.

The recommended processing temperature for this film is 70 F. Temperature control equipment should allow for holding the developer solution within plus or minus three-tenths of a degree, the other solutions within one or two degrees, and the wash water within one or two degrees of this value.

In processing the film, the jet antihalation backing must be removed before the film enters the color developer. A solution of the following composition is suitable for this purpose:

Prebath for Jet Backing Removal (Kodak PB-1)

	Avoirdupois—U.S. Liquid		*Metric*
Kodak Borax (sodium tetraborate) ($Na_2B_4O_7 \cdot 10H_2O$)*	20 lb	2 oz 290 grains	20.0 grams
Kodak Sodium Sulfate, desiccated	100 lb	$13\frac{1}{4}$ oz	100.0 grams
Kodalk Balanced Alkali	$6\frac{1}{2}$ lb	375 grains	6.5 grams
Water to make	120 lb	1 gal	1.0 liter

pH (70 F), 9.25 ± 0.05

Specific gravity (70 F), 1.098 ± 0.003

* In case it is desired to use a grade of borax having only 5 moles water of crystallization, the quantity should be reduced to 15 grams per liter. The quantity of Kodalk Balanced Alkali should also be increased to 10 grams per liter to adjust the solution to the proper pH value.

A treatment time of about ten seconds in this solution is sufficient to soften the backing. Longer treatment times may have adverse effects on the sensitometric characteristics. The film is then directed to a side tank containing a buffer wheel, which contacts the base side of the film. This buffer is motor-driven and rotates in a direction counter to and at a peripheral speed of about one-quarter of that of the film itself. The buffer wheel is adjusted so as to exert only a slight pressure on the film, thus minimizing chances of abrasion. Water is continuously supplied to the tank and removed particles are flushed to the sewer. Following the buffing operation, the film is given a brief spray rinse in order to remove any adhering particles of backing, especially those which might have become attached to the emulsion surface.

An efficient squeegee should be provided after this spray rinse to prevent excessive carryover of water to the color developer. The color-developer formula is as follows:

Color Negative Developer (Kodak SD-30)

	Avoirdupois	U.S. Liquid	Metric
Water, about 70–75 F (21–24 C)	96 gal	100 fl oz	800 ml
Benzyl alcohol	58 fl oz	3.9 fl drams	3.8 ml
Kodak Anti-Calcium, sodium metaphosphate, sodium hexametaphosphate or Calgon (Calgon, Inc.)	2 lb	115 grains	2.0 grams
Kodak Sodium Sulfite, desiccated	2 lb	115 grains	2.0 grams
Kodak Sodium Carbonate, monohydrated	50 lb	$6\frac{3}{4}$ oz	50.0 grams
Kodak Potassium Bromide	1 lb	60 grains	1.0 gram
Kodak Sodium Hydroxide, cold 10% solution	84 fl oz	$5\frac{1}{2}$ fl drams	5.5 ml
Kodak Color Developing Agent, CD-3, 4-amino-N-ethyl-N(β-methanesulfonamidoethyl)-*m*-toluidine sesquisulfate monohydrate	5 lb	290 grains	5.0 grams
Water to make	120 gal	1 gal	1.0 liter

pH (70 F), 10.75 ± 0.05
Specific gravity (70 F), 1.046 ± 0.003

In the above formula, the Color Developing Agent, CD-3, is a derivative of *p*-phenylenediamine, which does not normally produce "sensitization" in human skin. Its properties, in this respect, are similar to the well-known Kodak Elon Developing Agent.

An important ingredient of the formula is benzyl alcohol. This material serves as a "developer booster." Increases in benzyl alcohol content cause an increase in speed, contrast and fog level, whereas insufficient amounts tend to produce symptoms of underdevelopment. The effects are not equal for each of the three layers, however. The influence of development time on speed, contrast and fog is, likewise, not equal for the separate layers, nor are the relative effects the same as those obtained by variation of the benzyl alcohol content. Most of the other ingredients of the developer formula serve the same purposes found for black-and-white developers.

Following color development, the film is given a brief spray rinse before it enters the first fixing or stop bath. This minimizes the tendency for formation of carbon dioxide gas and possibility of blistering when the film passes into the acid stop bath. It also helps prolong the life of the latter solution. The formula is as follows:

First Fixing Bath or Stop Bath Formula (Kodak F-5)

	Avoirdupois	U.S. Liquid	Metric
Water, about 125 F (50 C)	72 gal	80 fl oz	600 ml
Kodak Sodium Thiosulfate (Hypo)	240 lb	2 lb	240 grams
Kodak Sodium Sulfite, desiccated	15 lb	2 oz	15.0 grams
Kodak Acetic Acid (28%)	5 gal 80 fl oz	6 fl oz	48 ml
Kodak Boric Acid, crystals	$7\frac{1}{2}$ lb	1 oz	7.5 grams
Kodak Potassium Alum	15 lb	2 oz	15.0 grams
Water to make	120 gal	1 gal	1.0 liter

pH (70 F), 4.25 ± 0.25
Specific gravity (70 F), 1.135 ± 0.003

This solution stops development and provides some hardening of the emulsion. It also converts the unused silver halide salts to complex thiosulfate salts, which can be removed by washing. The pH of the first fixing bath should be controlled within the limits indicated because high pH values result in formation of alum sludge, whereas lower pH values result in less effective hardening.

A water wash is used after the first fixing bath to remove the thiosulfate salts. Spray washing is preferred for this step. An efficient squeegee is also desirable to prevent undue carryover of water into the bleach tank.

The bleach bath is used to convert the metallic silver of the image and also the yellow filter layer to compounds which may later be removed by the second fixing bath. The formula for the bleach solution is as follows:

Bleach for Color Motion Picture Film (Kodak SR-4)

	Avoirdupois—U.S. Liquid		*Metric*
Water, about 70 F (21 C)	96 gal	96 fl oz	800 ml
Kodak Potassium Bromide	20 lb	2 oz 290 grains	20.0 grams
Kodak Potassium Bichromate	5 lb	290 grains	5.0 grams
Kodak Potassium Alum	40 lb	$5\frac{1}{4}$ oz	40.0 grams
Kodak Sodium Acetate*	$2\frac{1}{2}$ lb	145 grains	2.5 grams
Kodak Glacial Acetic Acid*	7 gal 26 fl oz	$7\frac{3}{4}$ fl oz	60.0 ml
Water to make	120 gal	1 gal	1.0 liter

Adjust pH to 3.0 ± 0.20 (70 F) with 10% sodium hydroxide solution
Specific gravity (70 F), 1.038 ± 0.003

---

* As a substitute for sodium acetate and glacial acetic acid, either of the following combinations may be used:

	Avoirdupois—U.S. Liquid		*Metric*
Sodium diacetate	42 lb	5 oz 270 grains	42.0 grams
and			
Sulfuric acid, concentrated	123 fl oz	8 fl drams	8.0 ml
or			
Sodium diacetate	42 lb	5 oz 270 grains	42.0 grams
and			
Sodium bisulfate	42 lb	5 oz 270 grains	42.0 grams

It is important to maintain the pH of the solution within the tolerance specified in order to insure efficient bleaching of the silver without bleaching the dye images.

Following the bleach solution, a water wash is used to remove soluble compounds from the film. A spray wash is desirable at this point. A suitable squeegee at the end of the operation is also desirable to prevent excessive carryover to the second fixing bath.

The film must be fixed at this stage. The composition of the second fixing bath is the same as that of the first fixing bath (Kodak F-5). It is not desirable, however, to recirculate the second fixing bath solution with the first fixing bath solution because bleach solution which has been carried over into the second fixing bath may cause stain. It is possible to recirculate the second fixing bath with the general hypo system used for black-and-white processing but processed film should be carefully inspected for any signs of stain. It is also possible to replenish the second fixing bath by overflow from the first.

A final washing operation follows. Most efficient washing is obtained with a spray wash.

As insurance against drying marks, a final bath containing a wetting agent is used. A number of wetting agents are suitable for this purpose, among which are Kodak Photo-Flo solution, Kreelon, Alkanol-B and Aerosol. A solution containing Kodak Photo-Flo is as follows:

	U.S. Liquid		*Metric*
Water. . .	120 gal	1 gal	1 liter
Kodak Photo-Flo Concentrate.	31 fl oz	2 drams	2.0 ml

If it is desired to use one of the other wetting agents in place of Kodak Photo-Flo solution, tests should be made to determine the optimum concentration. An efficient air squeegee should be used at the end of this operation to remove excess water and to help prevent drying marks.

Film drying conditions ordinarily employed at the present time for use with black-and-white negative films are satisfactory for this film. (Temperature about 70 to 80 F and relative humidity of about 40 to 60%.)

Establishing a Standard Process

With each individual installation, a period of testing is required to arrive at the proper conditions to give satisfactory results. During this initial testing stage, it is important to obtain as much data as possible relative to the mechanical and chemical conditions of the process and the corresponding photographic effects observed.

It is most convenient to record the data graphically, so that the processing conditions can be evaluated quickly and compared with the photographic results. Periodic readings of solution temperatures, flow rates, replenishment rates, machine speed and any other mechanical data can be plotted immediately on charts located in the control room near the processing machine. During the early stages of operation, such readings should be made frequently, say every half hour. When the processing conditions have been stabilized, the frequency of measurements can be reduced but in no case should they be entirely eliminated for routine operation.

In establishing a standard process and for process control, facilities for chemical analysis of the solutions are a requisite. In the early stages of operation, frequent analyses are necessary. In routine operation, such analyses can be made less frequently, according to schedule, unless some unforeseen difficulty occurs which requires detailed investigation. Chemical analysis data are preferably recorded in a graphical manner so as to be quickly available for inspection and comparison with mechanical and sensitometric control data.

Initially, the solutions are made up according to the formulas given above and each solution is checked to see that it has been mixed correctly. After making certain that the solutions have been adjusted to the correct temperature, a series of sensitometric strips is processed, in which the development time is varied over a short range on either side of the nominal time of twelve minutes. From these strips, integral density readings of the neutral scale to red, green and blue light are made and the corresponding characteristic curves are plotted. A time of development is then chosen for which the results are most nearly identical to the manufacturer's standard.

For the solutions other than the developer, the times specified in Table III are satisfactory and no additional changes should be required.

Table IV. Suggested Chemical Control Standards for Important Constituents of Various Processing Solutions for Eastman Color Films.

Solution	Constituent or chemical factor	Control standard
Prebath (Kodak PB-1)	pH (70 F)	9.25 ± 0.10
	Specific gravity (70 F)	1.098 ± 0.003
	Total alkalinity	31.5 ± 2.0
Color negative developer (Kodak SD-30)	Developing Agent CD-3	5.00 ± 0.25 g/l
	Benzyl alcohol	3.8 ± 0.4 g/l
	Sodium sulfite	2.00 ± 0.25 g/l
	Potassium bromide	1.00 ± 0.05 g/l
	pH (70 F)	10.75 ± 0.05
	Specific gravity (70 F)	1.046 ± 0.003
	Total alkalinity	40.0 ± 2.0
Color print developer (Kodak SD-31)	Developing Agent CD-2	3.00 ± 0.25 g/l
	Sodium sulfite	4.0 ± 0.5 g/l
	Potassium bromide	2.00 ± 0.10 g/l
	pH (70 F)	10.65 ± 0.05
	Specific gravity (70 F)	1.023 ± 0.003
	Total alkalinity	37.0 ± 2.0
First and second fixing baths (Kodak F-5)	pH (70 F)	4.25 ± 0.25
	Specific gravity (70 F)	1.135 ± 0.02
	Hypo index	36.0 ± 2.0
Bleach (Kodak SR-4)	Potassium bichromate	5.0 ± 0.5 g/l
	Potassium alum	Not critical
	Potassium bromide	Not critical
	pH (70 F)	3.0 ± 0.2
	Specific gravity (70 F)	1.038 ± 0.003

Process Control

The primary method of control is the adjustment of the mechanical and chemical variables of the process. Mechanical adjustments are made, when required, to keep the machine operating under standard conditions. These include adjustments for temperature, recirculation rate, film speed, etc. Periodic analyses for important constituents of each of the solutions are run and appropriate additions are made to keep the composition of the solutions within specified limits. In this way the process is always restored to a condition which is known to produce satisfactory photographic results. The control limits for each of the important ingredients are determined on the basis of the variations in photographic quality which can be tolerated. This emphasizes the importance of careful correlation of the chemical analysis and photographic data. Suggested limits for the important ingredients of the various solutions are given in Table IV.

To obtain the most uniform results, it is preferable to replenish the solutions continuously during operation rather than by making batch additions at intervals. Replenisher formulas for the various solutions are based on the consumption of the individual ingredients of the solutions as determined from chemical analysis data. The replenisher flow rate is adjusted to keep the composition of the solutions, including the oxidation products, within the appropriate limits. As has been pointed out by Koerner,[4] attempts to compensate for an off-standard chemical condition by changing the operating conditions can result in a process which is completely out of control. Intermittent replenishment fosters this situation.

As a secondary control method, sensitometric procedures are employed. Gray-scale exposures are made in an intensity-scale instrument on the particular emulsion number of the film being used for the picture negative. It is important to use an intensity-scale instrument for these exposures rather than a time-scale instrument, and the instrument should provide an intensity level close to that at which the film is normally exposed in a camera. This is necessary since the reciprocity-law failure characteristics[5] for the separate layers of a multilayer color film are not identical nor are these characteristics the same from one emulsion to another. It is desirable that the color quality of the illumination approximate that for which the film is balanced, tungsten at 3200 K.

The Eastman Processing Control Sensitometer may be used for exposing strips on Type 5248 Film. By operating the lamp at a current of 7.6 amp, a color temperature of approximately 3100 K can be obtained, which is sufficiently close to the recommended color temperature of 3200 K. A Kodak Wratten Neutral Density Filter No. 96, having a density of 1.3, is also required to limit the intensity for proper exposure.

The Herrnfeld Sensitometer* may also be used for making sensitometric exposures on Type 5248 Film, using an appropriate lamp and neutral density filter.

Where no actual sensitometer is available, it is possible to make sensitometric strips on a scene tester, such as the Herrnfeld* or Houston-Fearless† instruments. Sensitometric exposures can also be made in a printer which is provided with a full-frame step tablet made on 35mm black-and-white film. The color balance of the printer is adjusted in this case to give a neutral exposure through the tablet onto Type 5248 Film.

* Frank Herrnfeld Engineering Co., Culver City, Calif.

† Houston-Fearless Corp., Los Angeles, Calif.

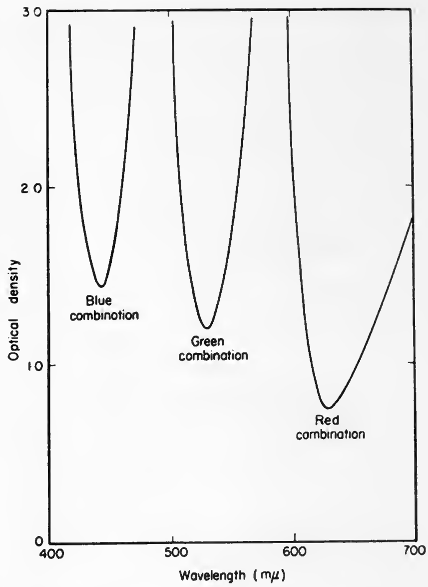


Fig. 2. Spectral density curves for an arbitrary set of filters for measuring red, green and blue densities of color films.

Ordinarily it should be sufficient to make only gray-scale exposures on the negative film for the purpose of measurement. However, a set of tricolor exposures on the same strip of film is useful for rapid visual examination. These can consist of only a few steps through a tablet having a higher gradient than that used for the gray scale. Suitable filters for such tricolor exposures are the Kodak Wratten Filters Nos. 29, 61 and 49. The exposed sensitometric strips are processed along with the picture negative footage. In the processed film, the gray-scale exposure appears brown rather than neutral in color because of the colored coupler mask remaining in the film.

The densities of the processed sensitometric strips might be evaluated in several ways but the most convenient method is to measure the integral density

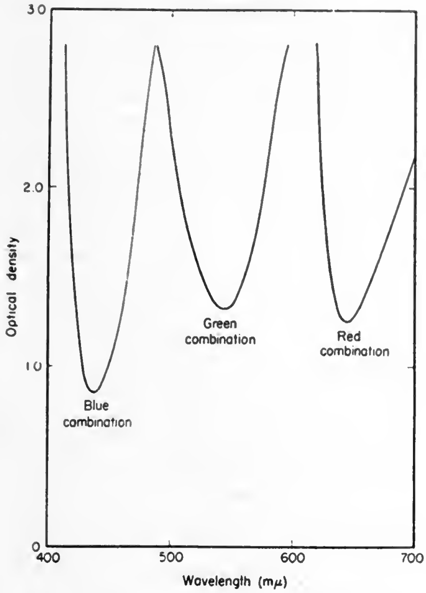


Fig. 3. Spectral density curves for filters designed to read integral densities which approximate effective printing densities of Eastman Color Negative Film and Eastman Color Internegative Film to Eastman Color Print Film.

of each step of the neutral scale to red, green and blue light. It is possible to make such measurements on densitometers equipped with any arbitrary set of tricolor filters such as the Kodak Wratten Filters Nos. 25 (red), 58 (green) and 47 (blue), or filters having specifications similar to those shown in Fig. 2.‡ This type of measurement is useful but has certain limitations.[6] It is better to choose the filters so that the readings represent the densities which the negative film presents to the print film. Typical spectral transmittance curves for the red, green and blue combinations of filters which can be used to measure a close approximation to printing densities of Type 5248 Film with respect to Type 5382 Film are shown in Fig. 3.

During the early stages of operation, it is desirable to plot complete characteristic curves from the integral density readings. Such information is valuable in work of investigational nature in the event of trouble. When a standard process has once been established, several sets of sensitometric strips should be run at intervals, preferably using a check emulsion. These curves should be averaged to give a single set of characteristic curves which should represent the results to be obtained for the standard process level. An idealized set of curves is shown in Fig. 4.

For process control, it is only necessary to read the densities of four steps of the

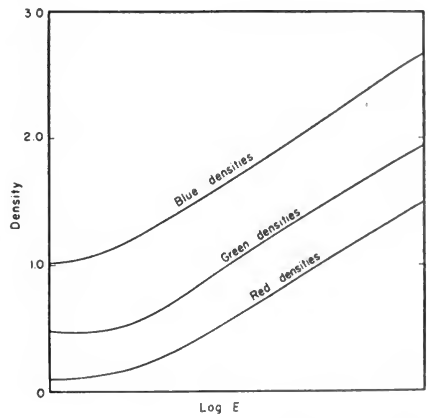


Fig. 4. *D*-log *E* curves for Eastman Color Negative Film, Type 5248.

Exposure, intensity-scale sensitometer, 1/50 sec.
Illumination, tungsten, 3150 K.
Density, effective integral printing density to Eastman Color Print Film, as read with filters shown in Fig. 3.
Densitometer, Eastman Electronic Color Densitometer, Type 31A.

‡ These filter specifications and those of Fig. 3 are for a densitometer utilizing a tungsten source operating at a color temperature of 3000 K and a photocell having an S-4 type surface.

gray scale, one in the toe, a second in the upper toe region, a third at about the middle of the scale and the fourth at the shoulder region of the curve. These densities should be plotted at regular intervals on charts in the control room. It should be recognized that the integral density curves to red, green and blue light do not represent the densities of the individual cyan, magenta and yellow layers, respectively. Each of the dyes has absorptions for regions of the spectrum other than that in which it is primarily intended to absorb. On this account, a change in any one of the process dyes will influence all three curves. The curves should be carefully examined to see which one shows the greatest departure from the standard conditions in attempting to analyze the cause of the processing variations.

Normally, sensitometric test strips are made on the particular emulsion number of film used for the picture negative being processed. The results obtained from such tests represent the combined effect of film and process variations. It is desirable, however, to determine what variation exists in the process itself, independent of the film characteristics and to detect any general drifts in the process from day to day. For this purpose a "check" emulsion may be used. A number of tests are run on several samples of this emulsion to determine its average photographic characteristics so that it will be known what can be expected of this film in a standard process. Every precaution is taken to store the film under good conditions (i.e., at low temperatures, say below 55 F) so as to minimize any changes in its characteristics over a reasonable period of time. Each day, several samples are selected and sensitometric exposures are made on them. The results are averaged and plotted to give the trend curve.

Care of Processed Negative

The processed color negative should be treated with a lacquer on both the emulsion and support sides, immediately after the drying operation. The Eastman Motion Picture Film Lacquer, Bead Type,[7] is satisfactory for this use. The lacquering operation may be carried out in the drying cabinet of the processing machine, using a bead applicator which confines the lacquer coating to the area between the two rows of perforations. This procedure is preferable to lacquering the entire film, because of troubles due to improper film positioning and excessive dirt, which might otherwise occur during the printing operation.

If scratches or abrasions which do not penetrate through the lacquer coating are accidentally put on the film, the lacquer can be removed and a new lacquer coating applied. Eastman Motion Picture Film Lacquer can be removed by treating the film for about two minutes in a 5% sodium carbonate solution, in Kodak Developer D-16 or in any regular black-and-white release positive developer. This treatment must be followed by a water wash, two or three minutes' treatment in an acid stop bath or fixing bath and a final wash. The water wash following the carbonate treatment should not be omitted, otherwise trouble may be experienced in complete removal of the lacquer. The water used for this wash should also be fresh and clean, since only a slight trace of acid may prevent removal of the lacquer. The acid stop bath or fixing bath is necessary to prevent formation of yellow dye in the highlights.

Every effort should be made to provide the best possible storage conditions for the valuable processed color negative in order to prevent damage or deterioration. Since the film has a safety support, no special precautions are required insofar as fire hazard is concerned. High temperature or high relative humidity, however, can cause change of the dyes in processed color films. Relative humidities above 60% promote the growth of molds and cause various physical defects. At very low relative humidities, motion-picture film may develop excessive curl and brittleness. The best conditions of storage are those where the film can be kept under controlled conditions of temperature and humidity. A relative humidity of 40 to 50% and a temperature of 70 F or less are most satisfactory for storage. Where it is not possible to furnish controlled humidity conditions, the film should be kept in a taped can, care being taken to have the equilibrium humidity of the film below 60% before the can is taped. The best insurance, however, is to prepare black-and-white separation positives in the manner described in a later section of this paper.

III. Eastman Color Print Safety Film, Type 5382 (35mm) and 7382 (16mm)

General Description

The new release print material is known as Eastman Color Print Safety Film, Type 5382 (35mm) and 7382 (16mm). This material is an integral-tripack, incorporated-coupler type film. Prints can be prepared on this film directly from a color negative made on Eastman Color Negative Film, Type 5248, or from Eastman Color Internegative Film, Type 5245. It may also be used for making prints from three-color separation negatives obtained in various ways.

This film is composed essentially of three emulsions sensitized to blue, green and red light and coated on one side of a single safety film support. The emulsions contain, in addition to the silver halide salts, appropriate dye couplers dispersed within them. On exposure and processing, a silver image and a dye image are produced in each layer, according to the exposure which each layer has received. The silver is later removed, leaving only the dye images as the final result in the picture area. The sound-track area, however, is redeveloped to give both a silver and a dye image in the track.

The structure of Eastman Color Print Film is shown diagrammatically in Plate III. The top layer is a gelatin overcoating to minimize the effects of abrasion during the handling of the film. The second layer consists of a green-sensitive emulsion in which is dispersed an uncolored coupler, which, during development, produces a magenta dye image. A gelatin interlayer separates the two top emulsion layers. The fourth layer consists of a red-sensitive emulsion containing a colorless coupler dispersed within it, which, during development, produces a cyan dye image. The fifth layer is a gelatin interlayer. The bottom layer is a blue-sensitive emulsion containing a colorless coupler which, during development, produces a yellow dye. All three emulsion layers are initially tinted purplish-blue in order to reduce light scatter and to improve sharpness. This color disappears during processing. On the side of the support opposite the emulsion layers is a removable jet antihalation backing.

Characteristics

Type 5382 Film is supplied in lengths of 1000 ft and is perforated according to the American Standard PH22.1-1953.* The 16mm film is supplied in lengths of 1,200 ft, perforated according to Proposed American Standards PH22.5 and PH22.12.†

Eastman Color Print Film is color-balanced to allow printing to be done by tungsten-quality illumination having a

* Dimensions for 35mm Motion-Picture Film, Alternate Standards for Either Positive or Negative Raw Stock, PH22.1-1953, *Jour. SMPTE, 60:* 67–68, Jan. 1953.

† Dimensions for 16mm Single-Perforated Motion Picture Film, PH22.12, and Dimensions for 16mm Double-Perforated Motion Picture Film, PH22.5, *Jour. SMPTE, 59:* 527, Dec. 1952.

color temperature of around 3000 K, with appropriate filter systems in the printing beam. The contrast characteristics are such as to give good tone reproduction when prints are made from color negatives made on either Eastman Color Negative Film, Type 5248, or Color Internegative Film, Type 5245.

A new magenta coupler is used in Type 5382 Film which results in an improvement in the reproduction of red hues, as compared with their reproduction with the earlier Type 5381 Film. The sharpness characteristics of the new print film are also noticeably better than those of the earlier material.

Changes in the sensitometric properties of each of the emulsion layers of this film may occur if the film is stored before exposure under adverse conditions of temperature and humidity. The problem is somewhat more serious with this material than with the color negative and the storage conditions are somewhat more critical. Eastman Color Print Film may be stored for periods up to three months at temperatures not exceeding 50 F without significant changes in properties. The lower the temperature at which the film is held, however, the slower will be the rate of change in properties during aging.

Eastman Color Print Film can be handled under illumination provided by a standard safelight fixture fitted with a Kodak Safelight Filter, Wratten Series 8. With direct illumination, where the light from the bulb shines directly through the safelight, the latter should be located not less than 4 ft from the working surface and a 15-w bulb should be used in the safelight lamp. Where indirect illumination is employed, a 25-w bulb may be used in the safelight lamp. It is advisable to make safelight tests in each room where the film is handled to be certain that the operating conditions are within safe limits.

Greater efficiency may be obtained by the use of a sodium-vapor lamp, suitably filtered, to absorb all energy emitted by the lamp except that confined to the narrow spectral region which includes the yellow lines (at about 589 mμ) of the sodium spectrum. A suitable combination of filters for use with a sodium-vapor lamp is the Kodak Wratten Filter No. 23A plus No. 57. A neutral tint absorption filter of sufficient density is also needed to reduce the intensity level to within safe limits. For this purpose, the Kodak Wratten Neutral Density Filter No. 96 can be used. The particular density should be chosen on the basis of tests made under the actual working conditions.

Table V. Processing Steps for Eastman Color Print Film, Type 5382 and 7382.

1. Prebath	10 sec to 1 min
2. Spray rinse	10–20 sec
3. Color development	12–15 min
4. Spray rinse	10–20 sec
5. First fixing bath	4 min
6. Wash	4 min
7. Bleach	8 min
8. Wash	2 min
9. Partial drying after squeegeeing	30 sec
10. Sound-track development	10–20 sec
11. Wash	2 min
12. Second fixing bath	4 min
13. Wash	8 min
14. Stabilizing bath	5–10 sec
15. Dry	15–20 min

The storage of the exposed film at 70 F up to eight hours produces no serious changes in the latent image. However, printing and processing schedules should be arranged to allow processing of the film as soon as possible after exposure. It is also desirable to keep the interval between exposure and processing the same from day to day or from one process to another.

Processing

The processing steps for Eastman Color Print Film with approximate times are shown in Table V. The formulas for the prebath, first and second fixing baths and bleach solution are the same as those used for processing Type 5248 Film. A different color developer formula is used for Type 5382 Film. In addition, special solutions are needed for sound-track development and for the stabilizing treatment.

For a specific installation, the processing times may be slightly different from those shown in the table, depending on the amount of solution agitation, the film velocity, amount of solution carry-over, machine design, etc. The recommended processing temperature is 70 F. Temperature control equipment should allow for holding the developer solution within plus or minus three-tenths of a degree of the recommended temperature and for holding the other solutions within one or two degrees and the wash water within two or three degrees of this value.

The formula for the color developer is as follows:

Color Print Developer (Kodak SD-31)

	Avoirdupois—U.S. Liquid		*Metric*
Water, about 70–75 F (21–24 C)	96 gal	100 fl oz	800 ml
Kodak Anti-Calcium, sodium metaphosphate, sodium hexametaphosphate or Calgon (Calgon, Inc.)	2 lb	115 grains	2.0 grams
Kodak Sodium Sulfite, desiccated	4 lb	230 grains	4.0 grams
Kodak Color Developing Agent CD-2 (2-amino-5-diethylaminotoluene monohydrochloride)	3 lb	175 grains	3.0 grams
Kodak Sodium Carbonate, monohydrated . .	20 lb	2 oz 290 grains	20.0 grams
Kodak Potassium Bromide	2 lb	115 grains	2.0 grams
Water to make	120 gal	1 gal	1.0 liter

pH (70 F), 10.65 ± 0.05
Specific gravity (70 F), 1.023 ± 0.003

A word of caution is in order about handling the Color Developing Agent CD-2. This may cause dermatitis (inflammation of the skin) among individuals exposed to it, and in some instances serious complications can result. Only a strict adherence to rigid discipline at all points where there is contact with this chemical or the developer solution will hold to a minimum the number of cases of chemical dermatitis among laboratory personnel.

Processing of the sound track is carried out in a side tank after partial washing after the bleaching operation. After leaving the wash water, the film is thoroughly squeegeed to remove all surface moisture. Thorough drying is advantageous in obtaining uniform sound-track development. Sound-track development can be carried out by means of an applicator wheel which applies the developer solution only to the sound-track area. An applicator wheel which is satisfactory for this operation is illustrated in Figs. 5 and 6. The sound-track developer is of such viscosity that with proper adjustment of the distance between the wheel and the film, a bead can be maintained to give application over the required area. A dial indicator may be used to indicate the bead distance and an arrangement such as that shown in the illustrations should be provided to allow adjustment of the distance for proper application. The applicator wheel dips into a small tray containing the developer. The latter should be continuously

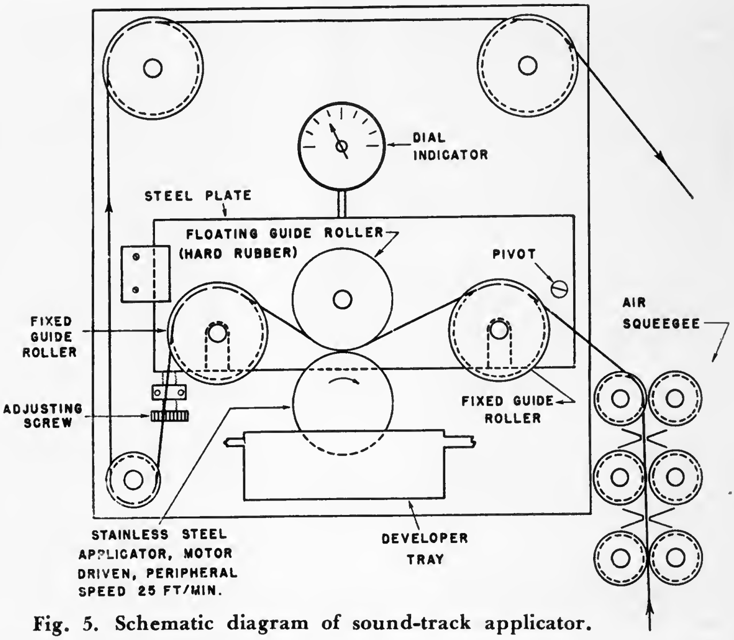


Fig. 5. Schematic diagram of sound-track applicator.

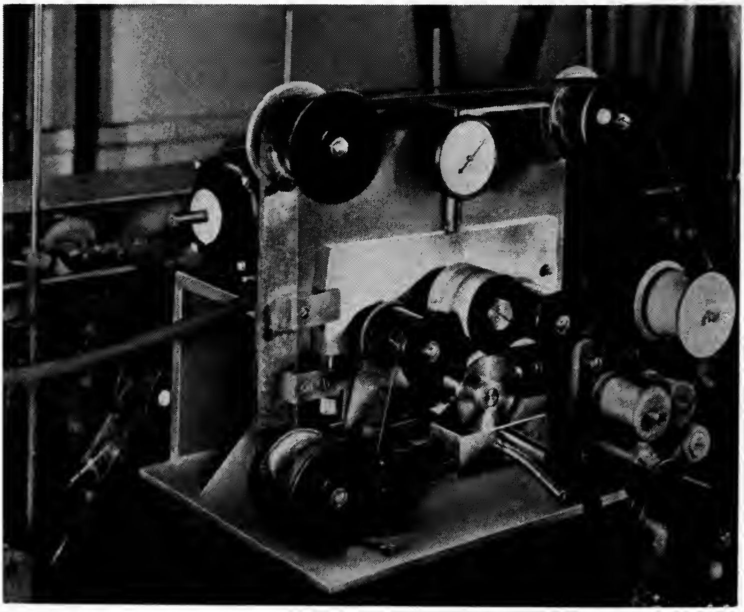


Fig. 6. Sound-track applicator.

replenished. The overflow must be connected to a separate drain rather than allowing it to enter the wash tank, since the contamination of the wash water by the sound-track developer may cause silver development in the picture area.

Sound-track development requires about 10 to 20 sec and a film path necessary to allow full reaction time must be provided before the film is returned to the wash water. Excess sound developer should be removed from the film before it is returned to the wash tank by means of a water squeegee so positioned as to direct a stream of water along the film surface away from the picture area toward the sound track. The rinse water is collected in a catch basin equipped with a separate drain.

The sound-track developer has the following composition:

Sound-Track Developer (Kodak SD-32)

	U.S. Liquid—Avoirdupois	*Metric*
Solution A		
Water	77 fl oz	600 ml
Kodak Sodium Sulfite, desiccated	$5\frac{1}{4}$ oz	40 grams
Kodak Elon Developing Agent*	$5\frac{1}{4}$ oz	40 grams
Kodak Sodium Hydroxide (caustic soda) while cooling, add with stirring	$10\frac{1}{2}$ oz	80 grams
Kodak Hydroquinone, dissolve completely	$5\frac{1}{4}$ oz	40 grams

* The Elon will not dissolve completely until the sodium hydroxide has been added.

Solution B		
Gum tragacanth (industrial grade)†	290 grains	5.0 grams
Place in a thoroughly dry, clean, one-liter beaker, then add:		
Alcohol (3A Specially Denatured)‡	$1\frac{1}{4}$ fl oz	10.0 ml

Swirl in the beaker until the mixture is distributed over the bottom and on the sides of the beaker to about one-third its height.

Add:		
Water, about 70 F (21 C)	38 fl oz	300 ml
Sodium hydrosulfite	8 oz	60 grams
Mix Solutions A and B and add:		
Ethylenediamine (60–70% by weight)	$2\frac{1}{2}$ fl oz	20 ml
Water to make	128 fl oz	1000 ml

(Note: This solution does not keep well and should be made fresh every 48 hr.)

---

† The purer grades of gum tragacanth are more difficult to get into solution and an industrial grade is therefore specified.

‡ Ethyl alcohol, specially denatured with technical grade wood alcohol. Minimum 190 proof. License must be obtained from District Supervisor of the Alcohol Tax Unit of the Bureau of Internal Revenue.

After the sound-track development, the film is returned to the wash tank to remove any remaining products, which, if carried over, would contaminate the second fixing bath. The second fixing bath and final wash treatments are the same as those described for the Color Negative Film.

The final washing is followed by a

formaldehyde stabilizing solution which improves the stability of the magenta image. This solution also includes a wetting agent to prevent formation of drying marks. The stabilizing bath has the following composition:

Stabilizing Bath for Color Motion Picture Film (Kodak S-1)

	U.S. Liquid—Avoirdupois		*Metric*
Kodak Formaldehyde, about 37% solution by weight	$4\frac{3}{4}$ gal to 6 gal	5 to $6\frac{1}{2}$ fl oz	40 to 50 ml
Kodak Photo-Flo Concentrate . . .	1 gal 26 fl oz	$1\frac{1}{4}$ fl oz	10 ml
Water to make	120 gal	1 gal	1.0 liter

The stabilizing treatment should be between 5 and 10 sec. Times of treatment longer than 10 sec, or excessive formaldehyde concentration, cause yellow stain.

The stabilizing bath is replenished continuously, allowing the overflow to pass to the drain. Excess solution is removed from the film by means of an air squeegee. To prevent contamination of the workroom with formaldehyde vapors, a ventilating hood should be provided over the stabilizing solution tank.

Because of the differences in refractive indices of the wet gelatin and wet coupler solvent remaining in the film, the latter has an opalescent appearance before drying. Upon drying, the refractive indices of the gelatin and coupler solvent become equal and the opalescence disappears. Drying conditions normally employed for drying black-and-white films are satisfactory providing there is sufficient air circulation so that the emulsion temperature is not excessive. High drying temperatures may cause excessive curl.

A typical processed print is illustrated in Plate II.

Establishing a Standard Process

As in the case of processing of the Color Negative Film, a period of operation will be required before a standard process can be established. The same procedures which were discussed in relation to the color negative film also apply here.

Replenishment of the solutions is preferably carried out in a continuous manner. Replenishment formulas and rates should be determined for each installation on the basis of the chemical analysis data.

Process Control

The primary method used for process control is the same as that described for the color negative process, namely, control of the mechanical variables and chemical composition of the solutions. Practical operating limits are determined by what variations in photographic quality can be tolerated. Some suggested limits for each of the important constituents of the solutions are given in Table IV.

As a secondary or corroborative means of control, sensitometric methods are employed. Sensitometric control strips should be exposed in an intensity-scale instrument which provides a light-intensity level and exposure time comparable to that which the film receives in a motion-picture printer. With the exception of the Eastman Processing Control Sensitometer, the types of equipment discussed in the section on Type 5248 Film are satisfactory.

The strips can be exposed to give single-layer exposures which will result in cyan, magenta and yellow dye scales in the processed film. The densities of the dye deposits can then be measured to give integral densities[6] which will describe the behavior of the individual layers of the print film. This technique is preferable to making a gray-scale exposure and reading integral densities therefrom, because it permits a more straightforward analysis of variations occurring in the film and/or process. With a tungsten light source operating at 3000 K, the following filter combinations may be used in the sensitometer, scene tester or printer for making the single-layer exposures:

Emulsion Layer to Be Exposed	*Kodak Wratten Filter*
Red-sensitive . . .	No. 29
Green-sensitive . .	No. 16 plus No. 61
Blue-sensitive . . .	No. 2B plus No. 49

The dye deposits can be measured on a suitable photoelectric color densitometer using red, green and blue light. In a densitometer equipped with a photocell having an S-4 type surface, such as is used in the Eastman Electronic Densitometer Type 31-A,[8] filter combinations having specifications similar to those given in Fig. 2 can be used satisfactorily.

Idealized curves for Eastman Color Print Film are shown in Fig. 7. The shouldering of the integral density curve for the yellow scale should not be interpreted to mean that the film lacks density to blue light in the high density regions. Both the magenta and cyan dyes have some density to blue light, hence when the three layer exposures are superimposed, the integral density to blue light in the higher density regions is adequate to give a neutral balance.

Projection of Prints

Release prints made on Eastman Color Print Film can be color-timed during printing to give proper color quality in the projected image for either tungsten or arc light projector illuminants. In most cases, prints will be balanced for use with the latter illuminant. In case it is desired to use such prints with a tungsten projector source, the light quality may be corrected approximately with a combination of a Kodak Wratten Filter No. 78B and a Kodak Color Compensating Filter CC-05G. A print which was originally timed for use with a tungsten projector source but which is to be used with an arc projector, may be corrected approximately with a combination of Kodak Wratten Filter No. 86A and a Kodak Color Compensating Filter CC-05M over the projector lens.

Care of Processed Prints

In order to obtain the greatest projection life for the color release prints,

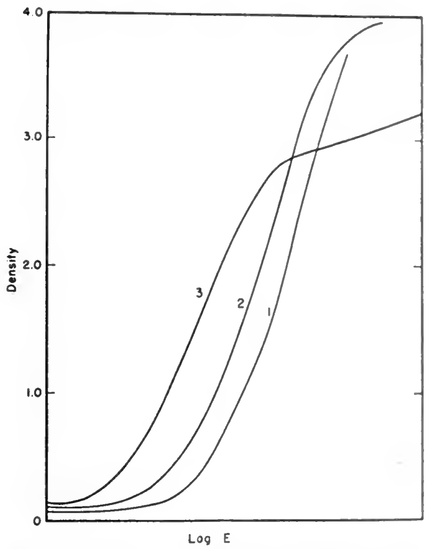


Fig. 7. *D*-log *E* curves for Eastman Color Print Film, Type 5382.

Exposure, intensity-scale sensitometer, 1/100 sec.

Illumination, tungsten, 3000 K, separate exposures through Kodak Wratten Filters (1) No. 29, (2) No. 16 plus No. 61 and (3) No. 2B plus No. 49.

Density, (1) red density of cyan scale, (2) green density of magenta scale and (3) blue density of yellow scale, all filters of Fig. 2.

Densitometer, Eastman Electronic Color Densitometer, Type 31A.

the same precautions concerning splices, lubrication, projector maintenance, etc., should be observed as those considered to be good practice in connection with black-and-white release prints.[9]

In the interest of obtaining the longest life during storage, the same conditions should be established as described for the color negative.

IV. Printing Eastman Color Negative Onto Eastman Color Print Film

It will be desired to print directly from color negatives made on Eastman Color Negative, onto Eastman Color Print Film in preparing work prints in color or small quantities of release prints from footage containing no special effects.

Printing Equipment

The ideal printing equipment for printing integral-tripack type color negatives onto similar-type release print materials provides facilities for automatic control of both the exposure and color balance for each scene.

For some purposes, however, such as in making color-balance tests and in preparation of dailies, printers of more limited versatility may be adequate. Such printers might provide only for adjustment of the exposure level for each scene at a fixed color balance and for manual adjustment of the latter. Various modifications of existing black-and-white printers have been made and used successfully in the industry for these purposes.

Modification of the color quality of the illumination in a printer can be accomplished in two general ways, by additive or subtractive methods.

In the additive method, red, green and blue light of appropriate spectral composition is obtained from either three separate filtered sources or from a single source in which the light is divided into three beams by use of beamsplitters or prisms and then filtered. The separate light beams are modulated and recombined at the printing aperture. Modulation of the intensities of each beam is effected by mattes, vanes, diaphragms or neutral density filters which are actuated automatically by means of information in the way of notches on the negative, magnetic track or other device. In this manner, both the color balance of the illumination and the overall intensity can be adjusted correctly for printing each scene.

An additive-type illumination system has been described by Streiffert,[10] in which the light from a single source is divided into three beams, each of which is filtered, modulated in intensity by rotatable vanes, then recombined at the printer aperture. A photoelectric monitoring system is used to adjust the intensity of the separate beams to provide the correct overall intensity and a punched tape serves to monitor the system for scene-to-scene color-balance changes. At a printer speed of 100 fpm, color-balance changes can be effected within about one-quarter of a frame. Some commercial laboratories have designed and built additive printers using other schemes.

The additive method of printing is the preferred method. The spectral pass-bands for the separate light beams can be selected by means of the proper filters so as to encompass any given group of wavelengths appropriate to the spectral transmittance characteristics of the negative dyes, and the spectral sensitivities of the separate layers of the print film. The use of narrow-wavelength bands in additive printing systems gives results which are superior in color saturation to those obtained using broader-wavelength bands or with subtractive systems. Printers employing the additive principle are also to be preferred because of their versatility.

In the subtractive method, a single light source is used and portions of the energy are subtracted in certain spectral regions by means of compensating filters, which are inserted in the beam. In some cases, neutral density filters are also used to keep the overall intensity constant for different filter combinations. Exposure timing is then accomplished by means ordinarily employed in black-and-white printers.

In subtractive type printing, the overlapping absorptions of the filters lead to certain difficulties. Ideally, such filters should have spectral absorptance curves with steep gradients, so that changes in the energy distribution of the printing illuminant can be effected over a specific bandwidth consistent with the negative dye image spectral transmittance characteristics and with the spectral sensitivity characteristics of the print film. Since this is not the case, combinations of such filters, especially when a large number is used, result in a loss in color contrast and saturation. Furthermore, it cannot be assumed that the removal of a given filter from a filter pack is equivalent to adding a complementary color filter of the same peak density. Examination of the spectral transmittance curves for two such packs will quickly show that they are not equivalent. Furthermore, if neutral density filters are used in conjunction with compensating filters to keep the overall intensity constant for various filter pack changes, the departure of neutral density filters from complete neutrality may introduce further errors. Such a system may become rather inefficient in the utilization of the available illumination. Finally, compensating filters cannot be expected to remain perfectly stable over long periods of time in high-intensity light beams, even when heat-absorbing glasses and forced ventilation are used.

A real challenge to printer designers and manufacturers exists to make equipment available to the industry which will be ideally suited for production color release printing.

Exposure of Color Print Film

Picture Exposure: Eastman Color Print Film requires considerably higher levels of illumination to obtain proper exposure than those ordinarily used in making black-and-white release prints. In a Bell & Howell Model D Printer modified for subtractive printing, with the necessary color-compensating filters in the beam but no neutral density filters, and equipped with a 300-w Bell & Howell Reflector Lamphouse, the proper exposure can be obtained through a color negative of average density at a printer speed of 40 fpm and a printer light setting of about 10. Under such conditions, the actual illuminance at the printer gate with no negative in position is of the order of 9000 lux. For higher production speeds, it would be necessary to use tungsten lamps of at least 1000-w rating.

In additive systems, the size of the lamps to be employed will depend on the efficiency of the optical system and the spectral bandwidth employed for each beam. For three light-source printers, lamps of 300- to 500-w rating should be adequate. For single light-source additive type printers, it is advisable to design the system to use a 1000-w lamp. This will usually permit printing to be done at reasonable production speeds even when the lamp is operated at voltages somewhat lower than the rated voltage.

Filters: In both subtractive and additive systems, it is desirable to insert a suitable heat-absorbing glass in the beam and to provide forced ventilation to keep the filters cool. A satisfactory heat-absorbing glass is the Pittsburgh Heat-Absorbing Filter No. 2043. In subtractive printing, the filter pack should contain, in addition to the compensating filters, a Kodak Wratten Filter No. 2B to absorb the ultraviolet portion of the energy emitted by the tungsten source.

Table VI. Filter Corrections With Subtractive Printing Systems.

Effect noted in reproduction	Correction needed in filter pack
Excessive yellow	Add yellow filter, (CC-05Y), etc.
Deficiency in yellow or excessive blue	Remove yellow filter, (CC-05Y), etc. or Add blue filter, (CC-05B), etc. or (CC-05M + CC-05C) etc.
Excessive magenta	Add magenta filter, CC-05M, etc.
Deficiency in magenta or excessive green	Remove magenta filter, (CC-05M, etc.) or Add green filter, (CC-05G etc.) or (CC-05C + CC-05Y) etc.
Excessive cyan	Add cyan filter, (CC-05C, etc.)
Deficiency in cyan or excessive red	Remove cyan filter, (CC-05C, etc.) or Add red filter, (CC-05R, etc.) or (CC-05Y + CC-05M) etc.

The Kodak Compensating Filters are supplied in yellow, magenta, cyan, red, green and blue in a series of six different densities for each color as follows:

CC-05Y, CC-10Y, CC-20Y, CC-30Y, CC-40Y, CC-50Y Yellow (blue-absorbing), with the same increments in the other colors.

The numbers of these filters, divided by 100, indicate the average density of the filter in the wavelength regions embraced by the absorption bands of the filter. They may be obtained in either gelatin sheets or in the cemented-glass type, but the former are more convenient for use in a printer. A qualitative description of the influence of these filters on the color balance of the final prints is given in Table VI.

In case it is desired to incorporate neutral density filters in the beam, in addition to the color-compensating filters, the Kodak Wratten Neutral Density Filter No. 96 is available in various densities, in gelatin sheet form or cemented-glass type.

For additive systems, each of the three light beams must be filtered appropriately to give red, green and blue light, respectively. It is possible to use various filters for this purpose, but better results are obtained if the filters are so chosen to give light confined to relatively narrow spectral regions with peak transmittances appropriate to the transmittance characteristics of the negative image dyes and to the peak sensitivities of the emulsion layers of the print film. For a three-light source type printer, a suitable combination of filters is as follows:

Light Beam	*Heat-Absorber*	*Wratten Filter No.*
Red	Pittsburgh Heat-Absorbing Filter No. 2043	70
Green	Same as for red beam	57 plus 15
Blue	Same as for red beam	47B plus 2B

In additive printers employing a single light source, the choice of filters will depend on the design of the beamsplitting system. Use of interference-type dichroic mirrors gives the most efficient use of the available light. Such mirrors can be made to give sharp cutoffs at specified wavelengths and high efficiency in regions of the spectrum in which they are intended to reflect. These mirrors can be combined with certain Kodak Wratten Filters to give the required spectral bands. The following specifications for bandwidth and wavelength of maximum transmittance for filter combinations are suggested:

Light Beam	Wavelength of Maximum Transmittance, $m\mu$	Bandwidth, $m\mu$
Red	690	675–700
Green	545	510–580
Blue	455	430–470

Color Balancing of Printers: In adjusting the color balance of a printer for use with a given emulsion number of print stock, the most practical procedure is to make a series of exposures at various light-intensity levels from a set of selected color negatives which are known to have received standard color negative processing. Such negatives should include several different types of subject matter and some, at least, should consist of close-ups of people. Such test negatives should preferably include in the original scene a gray scale and color patches. In practice, it is generally found that the gray scale is not reproduced as a gray scale in the print when the color balance of the printer has been adjusted to give the most pleasing picture quality. However, it is desirable to know just how such a scale is reproduced because this may be helpful when rebalancing a printer for a new emulsion number of print stock.

Picture judgments should be made, in the beginning at least, under the standard projection conditions which will be used for projection of the release prints. As experience is gained in making such judgments, it is possible to correlate them with judgments made with the aid of a suitable table projector.

When a new emulsion number of print stock is to be used, a new series of tests must be made to readjust the color balance of the printer for the new stock. If sensitometric comparison tests have previously been made on the two stocks, the results of such tests can be used as a rough guide in determining the changes which will be required for the new printer balance. Sensitometric comparison tests cannot be used as a precise guide in most cases because the conditions will often be governed by the particular portion of the characteristic curve of the print film which is utilized for printing each of the test scenes. Slight differences in toe shape or other characteristic may therefore influence picture quality more than is realized from an examination of the sensitometric curves.

Color-Timing: In printing color negatives onto Eastman Color Print Film, a difference in overall exposure amounting to about 0.04 log exposure unit (about one Bell & Howell Printer step) is apparent in the print. With respect to color balance, an even smaller change in the printing exposure of one emulsion layer relative to the other two is apparent as a color-balance change. The variations both in exposure and color balance which can be tolerated for a particular scene, however, will depend on the scene composition, the subject matter, the brightness range of the scene, and whether a deliberate departure from neutral balance must be aimed for in order to compensate for certain adaptation effects.

Color-timing demands considerable experience in printing a wide variety of scenes and careful observation of the results obtained in the final projected picture. It is helpful, in the beginning, to make a series of picture tests, on the equipment to be used for production printing, which will show the effects produced in the print by small changes in overall exposure and color balance. These test strips should be mounted and kept on hand for ready reference.

It is possible to estimate roughly what photographic effect will be obtained for a given color-balance change in the printer by observing a test print through previously calibrated viewing filters made up from selected combinations of color-compensating filters. A better system, however, is to employ some type of instrument, such as the Herrnfeld Scene Tester or Houston-Fearless Scene Tester, which will allow a test print to be made in which successive frames of the same scene are printed at a slightly different color balance. The frame which appears to have the best color balance for that scene can then be selected.

Even though each scene is correctly color-timed, further modification in the color balance may be required when a given scene is assembled with other scenes to give the cut negative for release printing. Such changes are often necessary to overcome adaptation effects resulting from observation of the scene immediately preceding the scene in question when the print is projected. These changes can only be decided upon after looking at the first trial release print.

Printer Control: It is important to have some means for frequent checking of the printer with respect to intensity and color quality of the illumination at the printer aperture. A suitable photoelectric method has been described in a previous paper by Horton.[11]

Sound-Track Exposure: The sound track may be printed optically or by contact from black-and-white sound negatives made in the conventional manner. Either variable-density or variable-width sound tracks may be printed satisfactorily. Under optimum exposure conditions, the frequency response obtainable with Eastman Color Print Film, Type 5382, is better than that obtainable with the earlier Type 5381 Film but is not equivalent to that obtained from black-and-white prints on Eastman Fine Grain Release Positive Film, Type 5302.

The sound-track image is exposed in the top two layers of the print film. This is accomplished by the use of the filter combination: Kodak Wratten Filter No. 12 plus No. 2B plus Kodak Color Compensating Filter CC-50C.

The exposure level should be adjusted on the basis of listening tests or, if equipment is available, on the basis of intermodulation tests for variable-density tracks or cross-modulation tests for variable-width tracks. With such tests, it is possible to determine the print density for the unbiased, unmodulated track which will result in adequate cancellation and minimum distortion in the reproduced sound. The optimum print density for the Type 5382 Film is somewhat lower than that for the Type 5381 Film.

Since the sound track consists of both silver and dye images, the densities should be determined on a densitometer which has been modified to permit density readings to be made in the infrared, as described by Lovick.[12]

V. Eastman Panchromatic Separation Safety Film, Type 5216

General Description

As outlined in Fig. 1C, black-and-white separation positives are prepared for the purpose of introducing special effects for creating dramatic emphasis, enhancing the mood of the story, etc. In preparation of such separation positives, it is also possible to correct portions of the original negative footage for contrast, density or color balance in cases where unavoidable or accidental variations have occurred in either or both the exposure and processing of the original color negative film. Even when not used for the above purposes, separation positives should be made to serve as protection masters for the valuable original in the event of damage to the latter during handling or printing.

Characteristics

Eastman Panchromatic Separation Safety Film, Type 5216, is a 35mm black-and-white panchromatic material having very low graininess and high definition. The graininess is of the same order as that obtained with Eastman Fine Grain Panchromatic Duplicating Film, Type 5203; but the contrast range available, when processed in most standard negative developers, is somewhat higher. The definition is superior to that obtained with Type 5203 Film. The panchromatic sensitivity of this film extends far enough into the longer wavelengths to permit use of a Kodak Wratten Filter No. 70 for preparation of the red separation positive. The film contains an absorbing dye in the emulsion, which is not fully removed during the processing. This dye imparts a greenish tint to the processed film.

The emulsion is coated on a clear safety base and the film is perforated with American Standard Negative perforations. Rolls are supplied in 1000-ft lengths with standard cores and winding.

The film may be handled under illumination provided by standard safelight fixtures, fitted with a Kodak Safelight Filter Wratten Series 8 or the Wratten 6B, ordinarily employed for use in handling x-ray materials.

Eastman Panchromatic Separation Safety Film may be stored under the conditions used for storage of Eastman Fine Grain Panchromatic Duplicating Negative Film, Type 5203. For periods of time up to one month, the storage temperature should not exceed 65 F. For storage periods up to six months, the temperature should not exceed 50 F.

Processing

This film may be processed in most developers ordinarily used for processing black-and-white negative materials. Since formulas for black-and-white negative processing vary widely from one laboratory to another, no specific times of development can be given. Where no particular negative formula is readily available, it is suggested that the Kodak Developer D-76 with additional potassium bromide (0.4 gram per liter) be used. Recommended processing temperature is 70 F. Fixing and washing operations may be the same as those used for regular black-and-white negative films. A typical set of processed separation positives is shown in Plate II.

In all cases, it is recommended that sensitometric test strips be prepared for the blue, green and red separation positives using in the sensitometer a tungsten light source and the filter packs normally used for making separation positives (given in a later section of this paper). A series of development times should then be given for each of the three separations, using the particular negative formula and equipment available and from these time-gamma curves may be derived in the usual way. A development time may then be chosen to give the desired gamma according to the requirements of

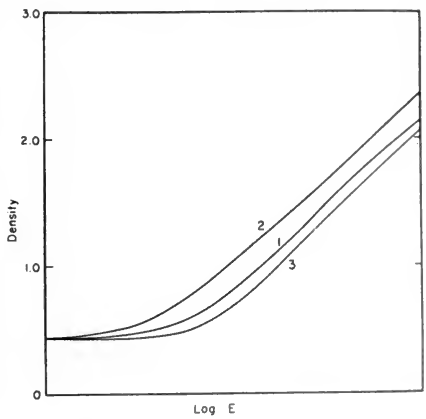


Fig. 8. ***D*-log *E* curves for Eastman Panchromatic Separation Film, Type 5216.**

Exposure, intensity-scale sensitometer, 1/25 sec.

Illumination, tungsten, 3000 K, plus Kodak Wratten Filters (1) No. 70 plus No. 96 (D = 0.40), (2) No. 16 plus No. 61 plus No. 96 (D = 0.10) and (3) No. 47B plus No. 2B.

Processing, Kodak Test Developer SD-28.

Density, diffuse density.

Densitometer, Eastman Electronic Color Densitometer, Type 31A.

the process. This is discussed in greater detail in a later section of the paper. Typical sensitometric curves for this film are shown in Fig. 8.

Densitometry

Densitometry of the red, green and blue separation positives may be carried out with any densitometer ordinarily employed for black-and-white films. If a visual-type instrument is used, a piece of fixed-out film or a green filter should be placed in the comparison beam of the instrument in order to facilitate making the readings.

Care of Processed Film

Proper storage of the processed separations is important in order to prevent differential shrinkage and to assure that perfect registration will be attained when these films are printed onto the subsequent color internegative or other materials. It is important that all three films be treated alike, as nearly as possible, after leaving the drying cabinet and up to the time they are printed. Each of the separations should be wound in the same direction on a 4-in. diameter core and placed in taped cans. It is also important that the temperature and humidity conditions of the various workrooms, wherever the separations are handled, be maintained within close limits, in order to minimize differences in shrinkage.

VI. Eastman Color Internegative Safety Film, Type 5245

General Description

Eastman Color Internegative Safety Film, Type 5245, is a new material designed to replace the former Type 5243 Film and is used as shown in Fig. 1C, for preparation of the color internegative from black-and-white separation positives. Such a color internegative will contain the special effects. The printing characteristics of the color internegative film are designed such that it can be intercut with original negatives made on Color Negative Film, Type 5248.

It may be feasible, of course, to prepare a color internegative of the entire footage which can be printed at a single exposure and color balance. This might be desirable, for example, for foreign release printing.

The film has the same structure as the earlier type Color Internegative Film, Type 5243.[2] A cross section is shown diagrammatically in Plate IV. The top layer of the film is a clear gelatin overcoating. The next layer consists of a blue-sensitive emulsion in which is dispersed a yellow-colored coupler. This coupler produces a magenta dye. The third layer is a clear gelatin layer. Beneath this is a blue- and green-sensitive emulsion in which is dispersed a reddish-orange colored coupler. This coupler produces a cyan dye. The fifth layer is a gelatin interlayer which separates the two bottom emulsion layers. The bottom emulsion layer is a blue- and red-sensitive emulsion which contains a colorless coupler. This coupler produces a yellow dye. On the side opposite the emulsion layers is a removable jet antihalation backing.

The dye image obtained in a given layer does not bear a complementary relationship to the spectral sensitivity of that emulsion layer as is found for Color Negative Film, Type 5248, and many other types of color films. The noncomplementary relationship between the dye image and spectral sensitivity of each layer is an advantageous scheme for avoiding loss of definition during the duplicating process.

Such an arrangement, however, causes no difficulty for the use intended, provided that the proper separation positives and filters are used to print each layer. Of course, if this film were used in a camera for original photography, false color rendering of each area of the original scene would be obtained.

Characteristics

The emulsion and latent-image keeping properties of Eastman Color Internegative Film, Type 5245, and the storage requirements are similar to those previously described for Color Negative Film, Type 5248.

Eastman Color Internegative Film is furnished on a clear safety base with jet antihalation backing in 400- or 1000-ft lengths. It is provided with American Standard Negative type perforations but having shorter pitch dimensions.*

The speed of this material is very low and a high-intensity light source and efficient optical system are needed in the printer to obtain sufficient exposure. The contrast characteristics are appropriate for printing onto Eastman Color Print Film, Type 5382. They are somewhat higher than those of the former Color Internegative Film, Type 5243, hence lower contrast separation positives are required when printing onto this material than with the earlier type film. The graininess characteristics of this material are improved over the earlier type film.

Processing

Processing of Eastman Color Internegative Film, Type 5245, is carried out in the same solutions and in the same manner as used for processing Color Negative Film, Type 5248, with the exception that the color development time is 9 min. As with the Type 5248 Film, the actual processing times will vary somewhat with individual processing machines, depending upon the degree of agitation employed, replenishment rates, etc. A typical processed color internegative is shown in Plate II.

Process Control

The procedures previously described for establishing a standard process for the Type 5248 Film apply equally well here. The sensitometer or scene tester used for exposing the sensitometric strips on Color Internegative Film should provide an intensity level and exposure time comparable to that which the film receives in a step printer. The sensitometric strips must be exposed in such a way as to give a neutral scale. This is required in order to permit calculation of the gammas for the separation positives. With such a neutral scale, approximate integral printing densities to red, green and blue light can be obtained using the filters shown in Fig. 3, in the densitometer.

To make the neutral scale exposure on Color Internegative Film, it is necessary to make three separate, superimposed exposures with red, green and blue light, using the same filter combinations used when printing the separation positives onto the Color Internegative Film. The exposure times for the individual exposures which will result in a balanced exposure for the neutral scale must be determined by trial on the equipment being used.

Suitable filter combinations for the three exposures are as follows:

Exposure	*Kodak Wratten Filter*
Red	No. 29
Green	No. 16 plus No. 61
Blue	No. 34 plus No. 38A

When a sensitometer or scene tester is not available, it is possible to make these superimposed exposures in a printer. This requires a black-and-white negative containing a step tablet on each successive frame, as nearly identical as possible. Such a negative could be made in a title camera by photographing a precalibrated gray-

* Proposed American Standard, PH22.93, 35mm Motion Picture Short-Pitch Negative Film, *Jour. SMPTE, 59:* 527, Dec. 1952.

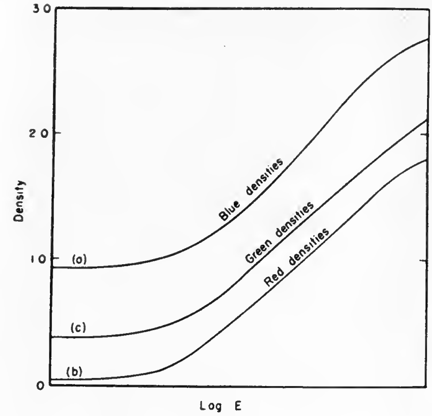


Fig. 9. *D*-log *E* curves for Eastman Color Internegative Film, Type 5245

Exposure, intensity-scale sensitometer, 1/25 sec.
Illumination, tungsten, 3000 K, with superimposed exposures through Kodak Wratten Filters (a) No. 29 plus No. 96 ($D = 0.60$), (b) No. 16 plus No. 61 and (c) No. 34 plus No. 38A plus No. 96 ($D = 0.20$).
Density, effective integral printing density to Eastman Color Print Film, as read with filters of Fig. 3.
Densitometer, Eastman Electronic Color Densitometer, Type 31A.

scale test object. Repeat exposures through this tablet, using the above filter combinations, could then be made onto the Color Internegative Film.

Idealized sensitometric curves for Eastman Color Internegative, Type 5245, are shown in Fig. 9.

Care of Processed Color Internegative

Since the color internegative will, in many cases, be intercut with original negative used for production release printing, it is important here, as in the case of the Type 5248 Film, to lacquer the film in order to protect the emulsion from permanent damage due to scratches.

Processed Color Internegative Film should also be stored under conditions which will prevent damage or deterioration. The information previously given with respect to storage of the processed Type 5248 Film, is equally applicable for this material.

VII. Making Separation Positives and Color Internegatives

General Procedure

The general procedure for making separation positives and color internegatives from original color negatives is illustrated diagrammatically in Plate V. The first step involves the preparation of the separation positives by means of exposures through appropriate red, green and blue filter combinations. The second step calls for printing these separations onto the proper layers of Color Internegative Film, using a different set of filter combinations. The resulting color internegative is then printed onto Color Print Film in the same manner as is done when printing from the original color negative.

Since the emulsion layers of Color Internegative Film have effective sensitivities which do not bear a complementary relationship to the color of the dye images produced in them, the actual color of the filter packs used in exposing the three layers may be misleading and some confusion may occur. To avoid this situation, it is helpful to refer to the blue separation positive as the "yellow printer," as indicated in Plate V, because it controls the amount of yellow dye image produced in the internegative. Similarly, the green- and red-separation positives are referred to as the "magenta printer" and "cyan printer," respectively. It is also helpful to refer to the filter combinations used for printing the separations onto the internegative film as the "yellow printer pack," the "magenta printer pack" and the "cyan printer pack," rather than by their actual color.

Equipment

The general requirements regarding equipment, the techniques to be employed and the precautions to be observed in order to obtain accurate registration, are much the same as those used in process work or with other color materials. When effects are to be included in the separation positives, it is necessary to employ an optical-type registering printer. If no effects are to be included, then a contact step printer of the registering type may be used.

In order to obtain exact registration in both making and printing the separation positives, it is essential that for both stages of operation the full-fitting registration pin of the printer fall in the same perforation relative to the frame being printed. This may be accomplished by having separate printer gates for each of the printing steps, with the full-fitting pin in the proper position, or by having two illumination systems in the printer.

In a contact printer, duplicate optical systems, each consisting of a light source, filterholder and shutter, allow printing to be done from either side of the gate. The separation positives can be made with the original color negative to the left of the separation film raw stock and the positives can be printed onto the internegative raw stock with the latter in the lefthand position. In this way, all printing can be done emulsion to emulsion and the registration pins can be positioned in the same perforations relative to the frame during both stages of handling the separations.

Since the speed of the separation and internegative films is very low, the printer used in both stages must utilize a high-intensity light source and an optical system of high efficiency.

Making the Separation Positives

Filters: For making separation positives from originals made on Eastman Color Negative Film, Type 5248, the following filter combinations are used:

Separation	*Kodak Wratten Filter*
Blue Separation or *Yellow Printer* . .	No. 47B plus No. 2B
Green Separation or *Magenta Printer* .	No. 16 plus No. 61
Red Separation or *Cyan Printer* . . .	No. 70

Exposure: Because of slight differences in curve shape, improper reproduction of certain colors in the highlight regions of the scene may result if the highlight areas are exposed on the extreme toe portion of the curve. On the other hand, if exposure is too great, problems may be encountered when printing the separation positives onto the internegative film because of insufficient light in the printer.

Making the Color Internegative

Filters: For exposing the Color Internegative Film from the separation positives, the following filter combinations are suitable:

Filter Pack	*Kodak Wratten Filter*
Yellow Printer Pack	No. 29
Magenta Printer Pack.	No. 34 plus No. 38A
Cyan Printer Pack.	No. 16 plus No. 61

Exposure: The exposure should be adjusted so that the overall density of the color internegative is slightly higher than a normally exposed original color negative. In no case should the color internegative be as light as an underexposed original negative. It is important that the picture be placed high enough on the characteristic curve of the internegative to avoid excessive distortion in shadow tone reproduction.

Calculation of Required Separation Positive Gammas: The overall gamma of the duplicating step must be unity if it is desired that the internegative have the same contrast characteristics with respect to the print film as those of the original negative. This will be the case, in general, although there will be some instances where it will be desired to increase or decrease the contrast of the internegative relative to that of the original. The contrast relationships in the duplicating system may be stated as follows:

$$\gamma_{(N \rightarrow 5216)} \times \gamma_{SP} \times \gamma_{(IN \rightarrow 5382)} = \text{Print-through } \gamma_{(IN \rightarrow 5382)} \quad (1)$$

where

$\gamma_{(N \rightarrow 5216)}$ = Process gamma of original color negative with respect to Separation Positive Film, Type 5216.

γ_{SP} = Process gamma of separation positive.

$\gamma_{(IN \rightarrow 5382)}$ = Process gamma of internegative with respect to Color Print Film, Type 5382.

Print-through $\gamma_{(IN \rightarrow 5382)}$ = Print-through gamma of internegative with respect to Color Print Film, Type 5382.

If the process gamma of the original color negative is determined with a densitometer equipped with a set of filters (such as those shown in Fig. 3) which give approximate printing densities with respect to Color Print Film, Type 5382, the correct value for $\gamma_{(N \rightarrow 5216)}$ can be calculated by using a correction factor. A different correction factor will be required for each of the filter combinations, thus:

$$P_r \times \gamma_{(N \rightarrow 5382)} = \gamma_{(N \rightarrow 5216)} \quad \text{(for the red combination)} \quad (2)$$

$$P_g \times \gamma_{(N \rightarrow 5382)} = \gamma_{(N \rightarrow 5216)} \quad \text{(for the green combination)} \quad (3)$$

$$P_b \times \gamma_{(N \rightarrow 5382)} = \gamma_{(N \rightarrow 5216)} \quad \text{(for the blue combination),} \quad (4)$$

where P_r, P_g and P_b are the constant correction factors which must be determined for the particular filters and densitometer used.

For the most general case, where the printing contrast of the internegative is to be equal to that of the original negative, we have:

$$\gamma_{(N \rightarrow 5382)} = \text{Print-through } \gamma_{(N \rightarrow 5382)} \quad (5)$$

Equation (1) then reduces to

$$P \times \gamma_{SP} \times \gamma_{(IN \rightarrow 5382)} = 1 \quad (6)$$

Hence,

$$\gamma_{SP} = \frac{1}{P \times \gamma_{(IN \rightarrow 5382)}} \quad (7)$$

Using the correction factors P_r, P_g and P_b and the measured process gammas from an internegative control strip, it is then possible to calculate the required gammas for the separation positives from Eq. (7).

In order to make use of Eq. (7), the internegative film exposure time for the control strip must not differ from that used for the final internegative and the density regions of the internegative characteristic curves chosen for measurement must be the *exact* regions upon which the picture will be printed. In addition, these regions (of red, green and blue curves) must be superimposed on the internegative control strip curve in order to avoid errors resulting from relative exposure displacement.

Acknowledgment

The authors wish to express their appreciation to all those people in the Manufacturing and Testing Divisions, the Color Technology Division, the Research Laboratories and the Motion Picture Film Department of the Eastman Kodak Company who have been responsible for the development work on these new films, and who have contributed so generously the information contained in this paper. On behalf of these people, the authors also wish to extend their thanks to those in the industry who, with their helpful suggestions and cooperation in making numerous practical tests, have helped to make this program a success.

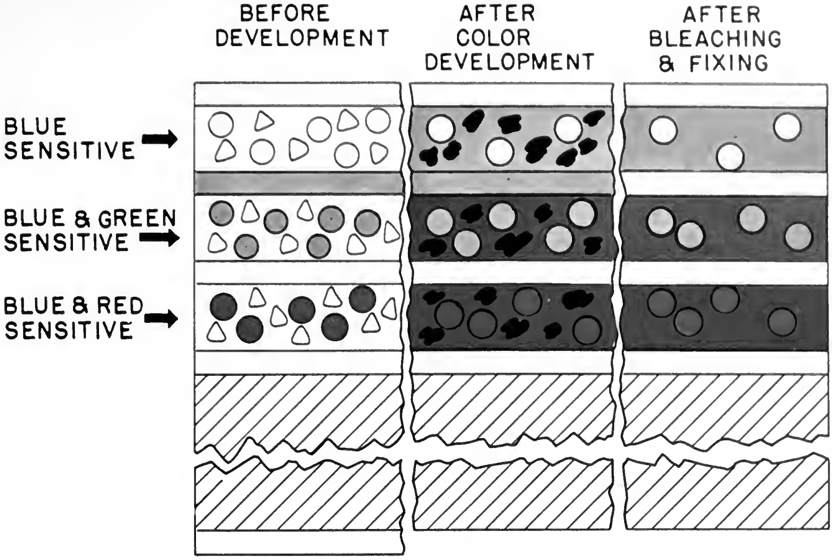


Plate I. Structure of Eastman Color Negative Film, Type 5248

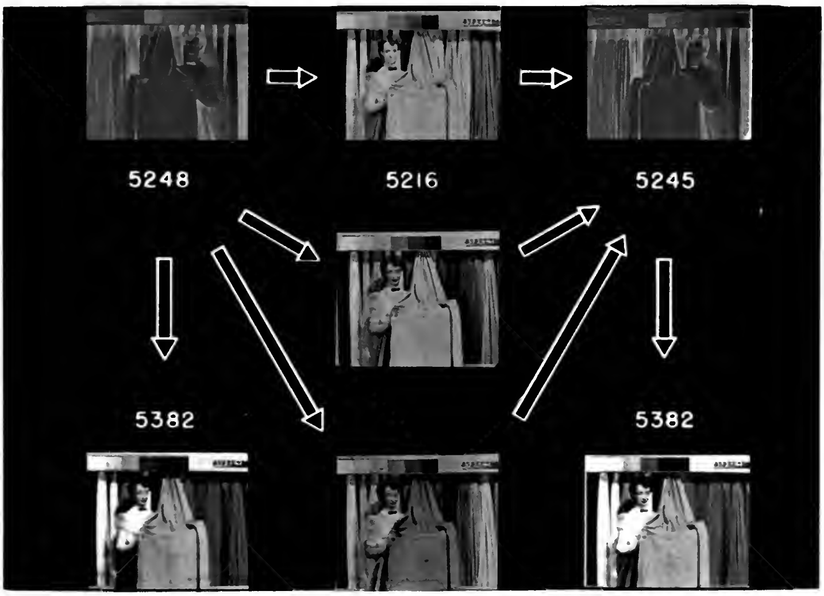


Plate II. Examples of Processed Films

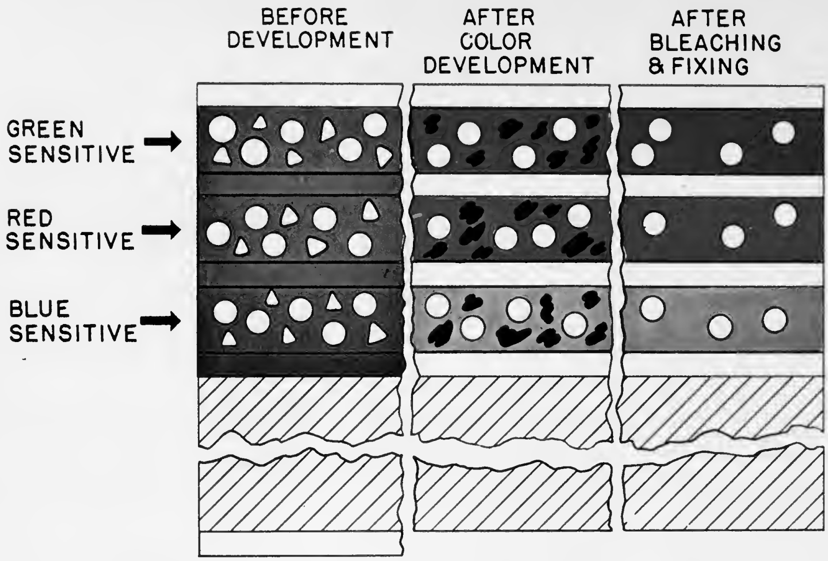


Plate III. Structure of Eastman Color Print Film, Type 5382

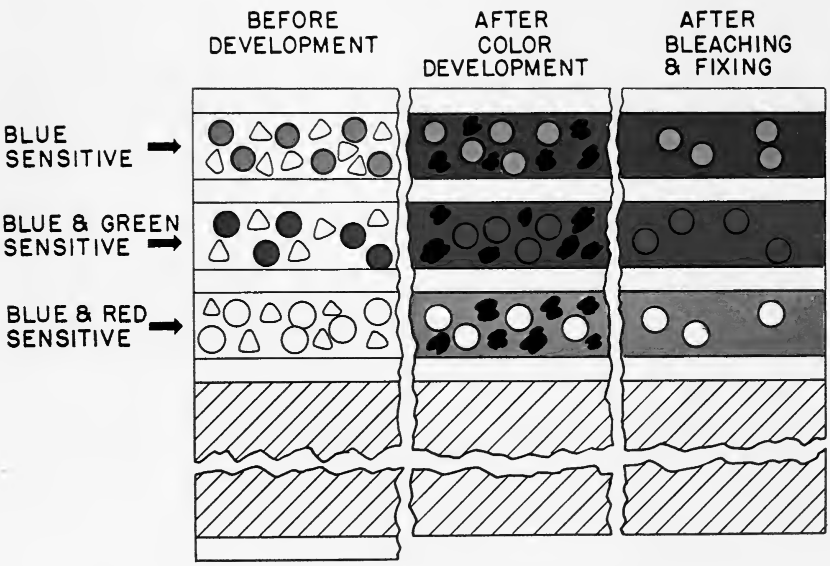


Plate IV. Structure of Eastman Color Internegative Film, Type 5245

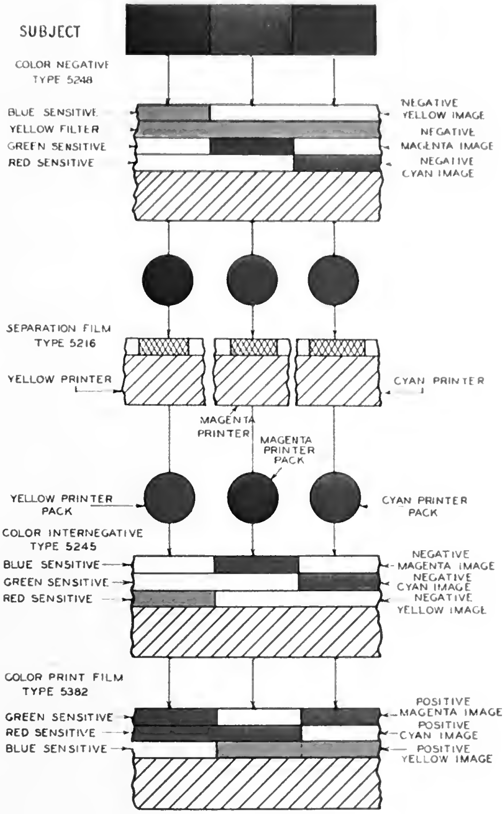


Plate V. Schematic Printing System

References

1. W. T. Hanson, Jr., "Color negative and color positive film for motion picture use," *Jour SMPTE, 58:* 223–238, Mar. 1952.
2. C. Anderson, N. H. Groet, C. H. Horton and D. Zwick, "An intermediate positive-internegative system for color motion picture photography," *Jour. SMPTE, 60:* 217–225, Mar. 1953.
3. T. H. Miller, "Masking: a technique for improving the quality of color reproductions," *Jour. SMPE, 52:* 133–155, Feb. 1949.
4. A. M. Koerner, "The problems of control of the color photographic processes," presented on April 30, 1953, at the Society's Convention at Los Angeles, and planned for early publication in the *Journal.*
5. J. L. Tupper, "Practical aspects of reciprocity-law failure," *Jour. SMPTE, 60:* 20–29, Jan. 1953.
6. A Report of the Color Sensitometry Subcommittee, "Principles of color sensitometry," *Jour. SMPTE, 54:* 653–724, June 1950.
7. R. H. Talbot, "A new treatment for the prevention of film abrasion and oil mottle," *Jour. SMPE, 36:* 191–197, Feb. 1941.
8. K. G. Macleish, "A transmission densitometer for color films," *Jour. SMPTE, 60:* 696–708, June 1953.
9. "Common Causes of Damage to 35mm Release Prints," available upon request to Motion Picture Film Dept., Eastman Kodak Company.
10. J. G. Streiffert, "A fast acting exposure control system for color motion picture printing," *Jour. SMPTE, 59:* 410–416, Nov. 1952.
11. C. A. Horton, "Printer control in color printing," *Jour. SMPTE, 58:* 239–244, Mar. 1952.
12. R. C. Lovick, "Densitometry of silver sulfide sound tracks," *Jour. SMPTE 59:* 89–93, Aug. 1952.

Objective Evaluation of Projection Screens

By ELLIS W. D'ARCY and GERHARD LESSMAN

This paper describes a method for measuring rear-projection screen brightness compared to the reflectivity of a standard magnesium block.

The increasing importance of wide-screen processes, three-dimensional projection, rear-projected educational films, process projection screens and large-screen television has put new emphasis on the projection screen as an optical element of the projection system and as the ultimate link between the audience and the film. The screen is, subjectively at least, the whole picture; and its apparent brightness, color and detail are unconsciously identified by the audience with the performonce of the entire projection system.

Although we know the approximate contribution of each individual element of the projection system to the end result, this common subjective estimate contains a germ of truth. There is in fact much more to be done at the screen by way of improving the brightness of the picture seen by the audience than at any other point in the optical system. For instance, although the limitations of projection equipment and presently available light sources make the attainment of even a small increase in screen illumination a commendable and difficult accomplishment, the effective screen brightness presented to the audience may vary 200%, according to the screen used.

Although many accurate measurements of screen characteristics are reported in the literature, their practical application has been limited, and the tendency has been to evaluate screens subjectively by simple visual comparison. This has been particularly true of rear-projection screens, because the lack of generally available instrumentation and of commonly accepted criteria and terminology has made objective evaluation difficult. Another reason for the absence of objective standards for rear-projection screens appears to be the greater intricacy of rear-projection illumination problems as compared to those involved in simple front projection. Front-projection screens act as simple diffusers which operate upon both the projected light and the ambient illumi-

Presented on April 22, 1952, at the Society's Convention at Chicago by Ellis W. D'Arcy and Gerhard Lessman, De Vry Corp., 1111 W. Armitage Ave., Chicago 14, Ill. (This paper was first received April 25, 1952, and in revised form September 18, 1953.)

nation according to the same set of reflection characteristics. Rear-projection or transmissive screens have separate and independent diffusion characteristics for the projected (transmitted) light and the ambient (reflected) light respectively. Their normal use under conditions of high ambient illumination emphasizes the importance of a knowledge of their reflective behavior for attaining good image contrast.

Three objective factors completely predetermine the behavior of rear-projection screens, and of front-projection screens as a special case thereof:

(a) photometric, including transmission and reflection at various projection and viewing angles, and color to the extent to which it affects the transmission and reflection;

(b) color, measured objectively, that is quantitatively by spectrophotometric methods, but for the purpose of establishing its subjective effect as mere color or departure from whiteness;

(c) resolution, measured as the size of the smallest detail resolvable upon the fine structure of the diffusing elements of the screen.

The subject of screen color appears to be adequately covered in an American War Standard[1] which prescribes spectrophotometric characteristics for diffuse-reflecting screens limiting the amount of permissible off-whiteness or tint. The authors consider this standard as acceptable and adaptable as well to rear-projection screens. Insofar as the screen color conforms to this standard, its effect is too slight to affect the photometric factors established by measurement with visually corrected photocells.

Screen resolution may be considered as the result of a complex of factors such as the graininess, line or facet structure of the screen, the depth of the diffusing elements, and the amount of transillumination from the highlights into adjacent shadow areas. An objective evaluation of screen resolution in terms of minimum detail size resolvable has become significant because a concept of small-screen, narrow-angle viewing for educational projection, stimulated by the success of television, has created some interest in small rear-projection screens of high resolution and brightness. Because of the large amount of experimental work to be reported, the authors plan to present their work on screen resolution in a subsequent paper.

What we have termed the photometric factors in objective screen evaluation derive from the simply understood characteristics of reflectance and transmittance of the screen when illuminated at various projection angles and as viewed from different viewing angles. Goniophotometric reflectance and transmittance, especially at singular points due to the influence of specular (glossy, nondiffuse) reflection or normal (nondiffuse) transmission, although readily comprehended as such, cannot be directly obtained experimentally nor evaluated visually. Photoelectric cells measure light intensity directly. The eye and visual photometers evaluate brightness by comparison, brightness being indeed the only objective comparative factor meaningful to the eye. Inasmuch as intensity is directly related to brightness as a function of the cosine of the angle of view, it is believed that a comparison of the brightness of a screen under any assumed condition of observation with the brightness of a standard material of universal acceptance would be objectively valid because of the relative ease and accuracy with which the corresponding intensity and angle measurements can be accomplished both upon the screen and the standard, and because of the instinctive subjective appeal of brightness as a direct visually significant quantity.

Freshly scraped chemically pure magnesium carbonate blocks were chosen as a standard conforming most closely to the well-known Lambert cosine law theoretical diffuse reflector. This standard is readily available to all, and departs so little from the theoretical cosine law diffuser that recomputation from the standard to a theoretical basis did not appear to be justified by the application intended. Our results are reported as "brightness ratios" to the brightness of magnesium carbonate under like conditions of illumination at various projection and viewing angles taken as unity. This approach is in accordance with the methods of an American War Standard[2] on reflective diffusing screen brightness characteristics whose terminology and methods appear to be appropriate and practical. Because of the rather large range of the brightness ratio ordinate, and because of the logarithmic visual response of the eye, a logarithmic brightness ratio plot was selected. A polar plot of the viewing angle was decided upon, because the angular distribution of light is more readily apparent from simple inspection of such a plot. The term "effective brightness gain" in use by some investigators[3] is merely a special case of a brightness ratio taken at the point of maximum brightness and as such has only limited usefulness, as will become apparent subsequently.

Analogous reasoning justifies this basis for transmission measurements. In this case, a hypothetical screen which diffuses all the incident light in a cosine distribution would yield the same intensity measurements and would have the same brightness at equal illumination as the standard. Similarly, the high intensity recorded when measuring a glossy or specularly reflecting material would be equivalent to the high intensity which would be recorded if a very transparent screen or no screen at all were set up in the transmission measurement position.

The instrument used for our measurements (Fig. 1) will be seen to be an elaboration of the goniophotometer built in 1920 by Loyd A. Jones,[4,5] of Eastman Kodak Co., in which the visual photometer head has been replaced by an accurate photoelectric photometer head and certain improvements in design have been effected. It will also be recognized as a refinement of the apparatus of Berger.[3] The instrument comprises a wooden base on which is mounted a lamphouse and two coaxial turntables. The upper turntable supports a rack which holds either the screen or a standardizing block of magnesium carbonate. An extension of the lower turntable supports a pedestal-mounted photometer head, connected by flexible leads to a bias network and a Ballantine vacuum-tube voltmeter. The several turntables are provided with indexing pins and holes for accurately indexing either the screen or the photometer head at 15° intervals.

A diagrammatic view of the instrument (Fig. 2) illustrates its function in reflectance measurement. The photometer head consists of an electrically and optically shielded housing for an objective lens and a lead sulfide photoelectric cell. The objective lens focuses a small image of a spot of light on the screen at the entrance face of a light pipe prism, a standard component of the De Vry sound-optical system, which scrambles or integrates the light and transmits it to the sensitive area of the lead sulfide cell with less loss than would result were an integrating sphere used.

The lamphouse encloses a 6-v, 18-amp vertical ribbon filament lamp, whose filament is directly imaged upon the screen. The light transmitted to the screen is freed from infrared radiation by a phosphate glass heat filter and is substantially white at a color temperature of approximately 2848 K. In order to provide a modulated input for the vacuum-tube voltmeter amplifier, light from the lamp is interrupted at a rate of 600 cycles/sec by a motor-driven light chopper disc. The brightness of the lamp is of course accurately

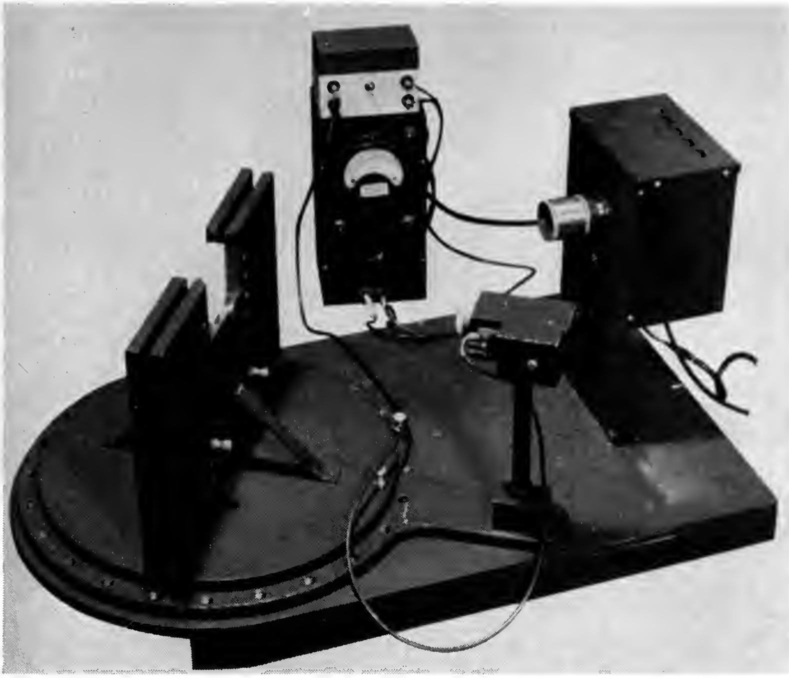


Fig. 1. Goniophotometer, with magnesium carbonate block in position for standardizing.

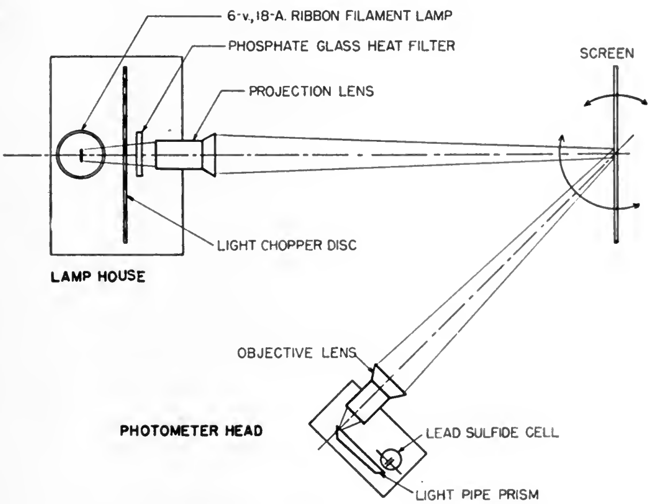


Fig. 2. Schematic diagram of goniophotometer.

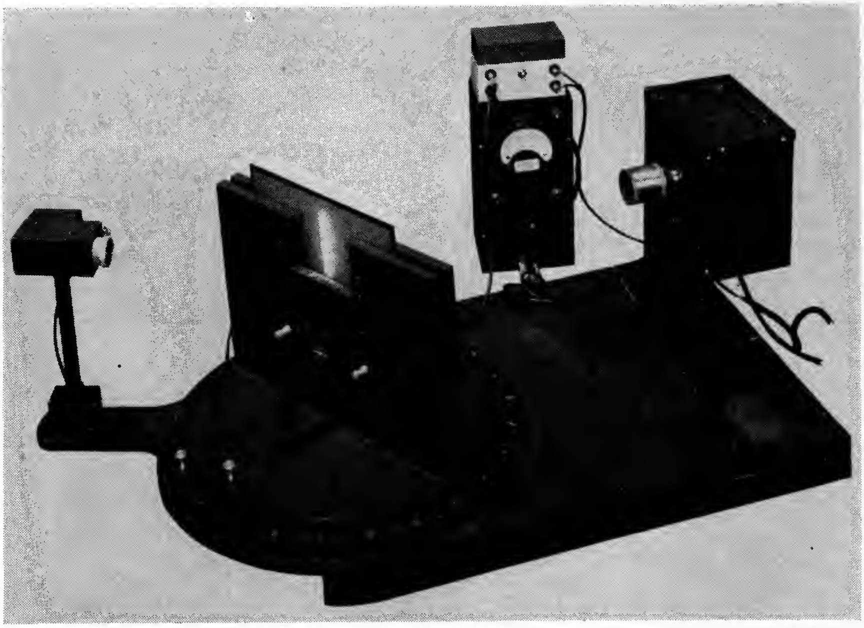


Fig. 3. Goniophotometer arranged for transmission measurements.

maintained through careful control of the supply voltage.

The physical dimensions of the apparatus are such that the half-widths of the light beams projected or picked up by the photocell are less than 1.5°.[2]

For transmission measurements (Fig. 3) the photometer head is positioned to pick up light from behind the screen. Angular adjustment of the screen and photometer head can be made with equal facility as in taking reflection measurements.

The probable absolute accuracy of this instrument as between separate sets of readings is believed to be well within 5%. The accuracy within any one set of readings (one goniophotometric curve) is believed to be about 2%.

Inasmuch as the instrument reads intensity directly and the intensity distribution of the magnesium carbonate is known to follow the Lambert law quite closely, a series of measurements was made and plotted against a theoretical cosine law curve (Fig. 4). The close correspondence is obvious and attests to the accuracy of our measurements. In measuring screen brightness the simple ratio of the screen intensity distribution to that of the magnesium carbonate standard was plotted as the brightness ratio, thus disregarding for practical purposes the few per cent difference between the standard and theoretical cosine law diffuser. As a test example, a good commercial matte white screen was measured and plotted (Fig. 5) in terms of the ratio of its brightness to that of magnesium carbonate under equal conditions of illumination. It will be noted that the brightness, although lower than that of magnesium carbonate, has the same semicircular distribution pattern, indicating that it is a Lambert law diffuser and that like all true Lambert law diffusing surfaces its brightness distribution is practically

Fig. 4. Goniophotometric curve of magnesium carbonate standard versus theoretical cosine law curve.

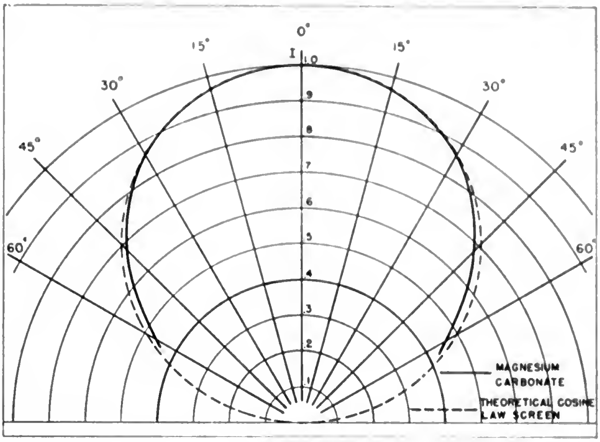


Fig. 5. Commercial matte white screen.

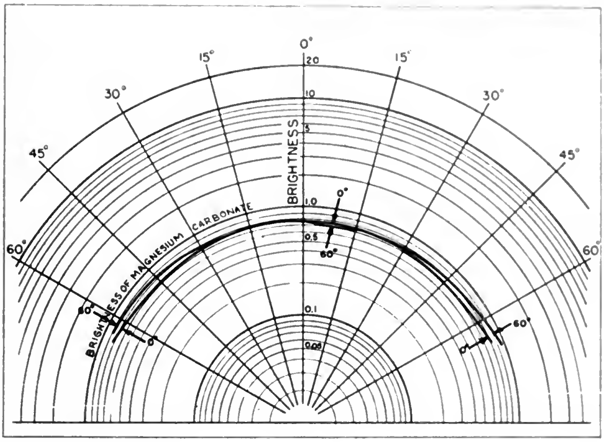
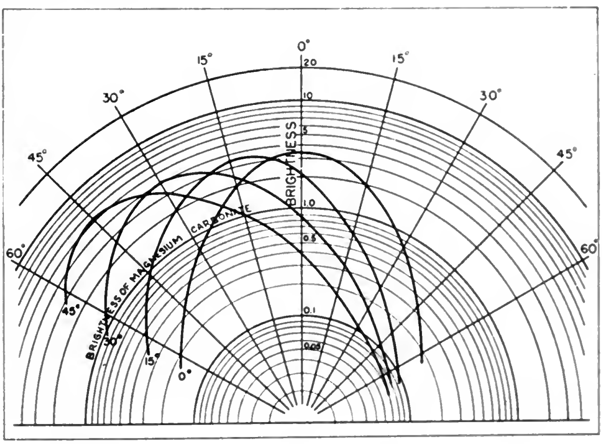


Fig. 6. Aluminized stereo projection screen.



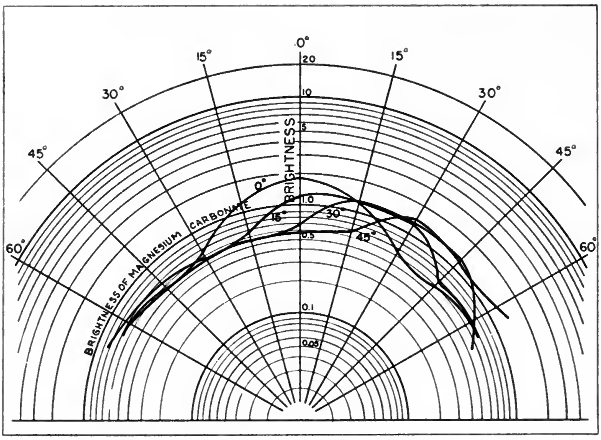


Fig. 7. Typical beaded screen.

unaffected by the angle of incidence of the projected light. This is apparent from the almost congruent 60° projection angle curve. As a further example of the type of results obtainable with our instrument and method of plotting, we present the brightness ratio curves of a rather specular type of screen (Fig. 6), a typical commercial aluminized screen used for stereo projection. The gain in center brightness of this screen, over four times that of magnesium carbonate, is quickly lost at even relatively small viewing angles, so that the so-called "brightness gain" at the normal viewing angle is very deceptive as to the screen's true performance under all conditions except specular viewing.

The next screen measured was a typical commercial beaded screen (Fig. 7). The interesting features of the curves for this screen are the basically cosine law distribution pattern of the screen except at the peaks, and the fact that the peak brightness occurs near but not exactly at the angle of incidence instead of at the opposite angle, a characteristic common to beaded reflective type screens.

The data on these three reflecting-type screens have been presented chiefly to illustrate the method of measurement and plotting, similar data for reflective-type screens having appeared in the literature[4–8] over an extended period. These data have been qualitatively properly interpreted in the past, particularly with reference to the selection of screens whose distribution curves complement the geometry of the theater[7] within which they are intended to be used. To our knowledge, however, there has been no attempt to correlate screen brightness characteristics with ambient light conditions in order to evaluate the available contrast or highlight to shadow brightness ratio. We shall elaborate upon this topic later, but at this point it must suffice to state that as between two front-projection screens, each having similar distribution curves, the maximum available contrast will be the same for both screens for equal conditions of projected and ambient illumination. The best front-projection screen, other factors being equal is simply the brighter one. This is definitely not true of rear-projection screens, as we shall show.

As an example of a typical rear-projection screen we shall now present the transmissive and reflective brightness ratio curves for a well-known commercial plastic rear-projection process screen (Fig. 8). Inspection of these curves

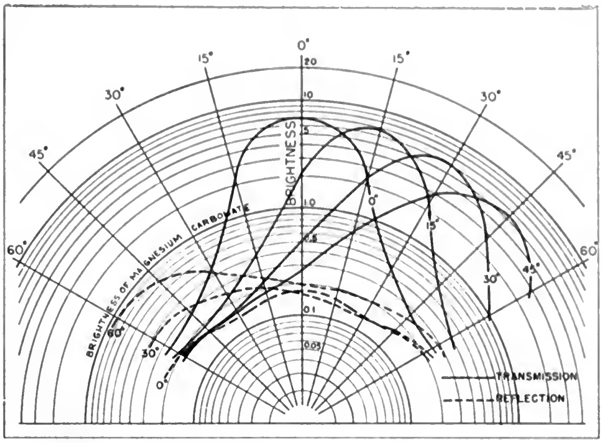


Fig. 8. Plastic rear-projection screen.

reveals that the transmissive brightness curves are similar in shape at different projection angles although their peaks are displaced at viewing angles in line with the corresponding angle of projection. The reflected brightness curves are a different family of similar curves and their specular peaks are of course at the angle opposite to the angle of projection. It is apparent that the brightness of the screen due to projected or ambient light of any specified intensity or direction can be read from these curves for any desired viewing angle, and that the brightness ratio or contrast range of highlight and shadow areas can thus be computed and plotted for any specified set of conditions. A natural desire to utilize the information exemplified by the above curves for evaluating a figure of merit should be restrained until the significance of these factors to the actual performance of the screen is clear. It is of course tacitly assumed that the resolution and color as well as the mechanical properties of the screen are satisfactory. In other words, one must have a screen before valid photometric measurements can be made on it. We shall, however, show a few brightness ratio curves for screens which do not have entirely satisfactory resolution in order to illustrate the photometric characteristics of the special materials of which they happen to be made.

Unlike simple reflective diffusing screens, transmissive diffusing screens may have characteristic reflection curves differing widely in shape and size from the transmission curves, so that a relatively inefficient transmissive screen of the "black" type, having a low transmissive brightness ratio, may yield an available picture contrast range far higher than a screen of greater light efficiency but proportionately higher reflecting power. It is necessary, however, that the transmissive brightness ratio meet certain minimum requirements, otherwise the picture will appear dim to the ambient illumination adapted eyes of the audience. This topic is no doubt being extensively investigated by the Society's Screen Brightness Committee, whose symposium on Screen Viewing Factors[9] ably developed certain aspects which are not within the scope this paper. The need for preserving a minimum level of screen brightness in the presence of unavoidable ambient or surround illumination diminishes the possibility of obtaining high contrast in the presence of high ambient illumination sometimes thought to reside in extra-dense black transmissive screens. Such dense screens simply do not give a bright enough image at the illuminations possible with available projectors and light sources. Before going deeper into these considerations we wish to illustrate the brightness characteristics of some different types of rear-projection screens.

Figure 9 illustrates the brightness characteristics of a black plastic rear-projection screen similar to the process screen (Fig. 8) just shown except for its blackness. Comparison of the two sets of curves reveals that the black screen has a broader brightness distribution out to 15° or 20° and therefore less of a hot spot, and that the ratio of the transmitted brightness to that of the reflected brightness is larger; that is, there is greater contrast. The facility with which such comparisons can be made is one of the advantages of the logarithmic plot. A simple measurement of the ordinate difference between the transmission and reflection curves or between any other two points of interest represents a direct ratio, which can be read off against the ordinate scale.

Figure 10 illustrates the photometric properties of a rear-projection screen which consists essentially of a black beaded coating on glass. The transmission of this screen is much less than that of the black screen just shown but is characterized by a flatter angular distribution which results in less of a hot spot. This advantage is offset by the comparatively high reflectivity of the screen, which is not therefore capable of yielding as high a contrast range as the previous screen. This screen possesses a slight gloss which becomes rather specular at steep projection angles as shown by the 60° incidence reflection curve. The resolution of this screen is fair, corresponding to a beaded reflective screen.

Figure 11 illustrates the properties of an experimental rear-projection screen sample made by the manufacturers of the screen just shown. This is a very dark black beaded coating on plastic. Although the central brightness along the transmitted ray is almost the same as that of the previous screen, the angular fall-off is very rapid, which accounts for the low overall light efficiency of this screen. This screen can hardly be illuminated sufficiently to establish a bright enough picture to compete with reasonable ambient illumination. The screen suffers from a very high gloss which is evinced by the very steep reflection curves, which indicate a reflected brightness ratio at specular points greater than the brightness due to direct transmission. This means that the gloss from ambient illumination will, at some viewing angles, completely wash out the picture contrast.

The next two figures illustrate two rear-projection screens of still another manufacturer. Figure 12 represents an emulsion on white opal glass type of screen. Figure 13 represents the characteristics of an emulsion on black opal glass type of screen. The characteristic curves of these two screens are very similar in shape and distribution except that the brightness ordinates of the black screen are only about half the value of those of the white screen, with the white screen having on the whole an apparent contrast range, or ratio between transmissive and reflective brightness, greater than the black screen. Nevertheless even casual inspection establishes the obvious fact that the black screen has the higher contrast and is, for most applications, the better screen. This means that under some conditions the photometric characteristics taken by themselves are insufficient although valid objective criteria of screen performance. In this particular case, the white screen (Fig. 12) is afflicted with so much halation resulting from sideward diffusion or transillumination of light from the highlight into the shadow areas, that the contrast range of which the screen might be capable on the basis of the photometric curves cannot be realized ex-

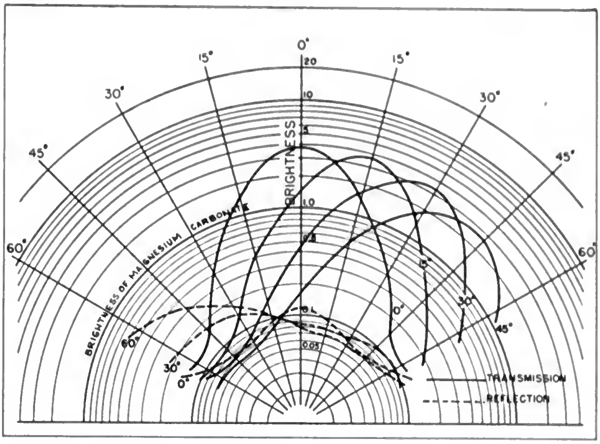


Fig. 9. Plastic black rear-projection screen.

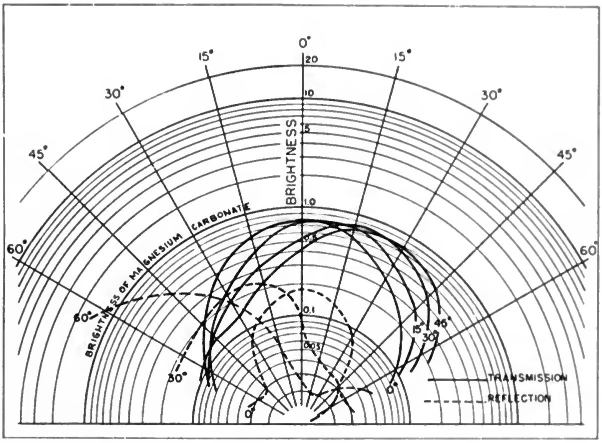


Fig. 10. Black beaded coating on glass.

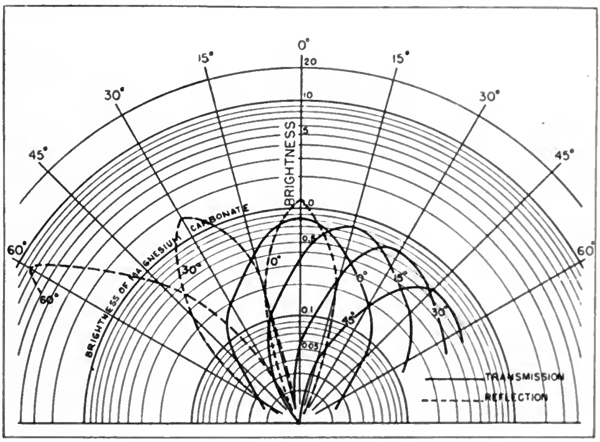


Fig. 11. Dark black beaded coating on plastic.

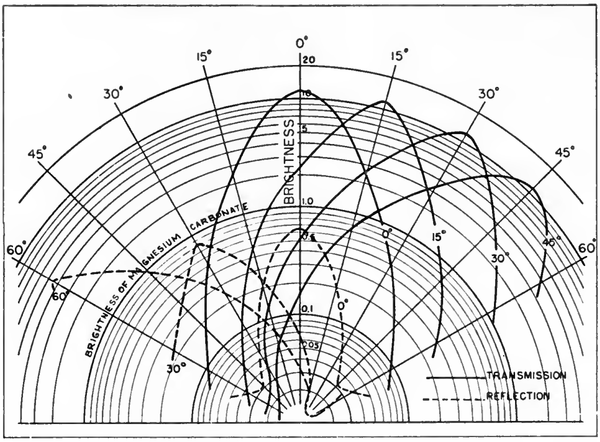


Fig. 12. Emulsion on opal glass.

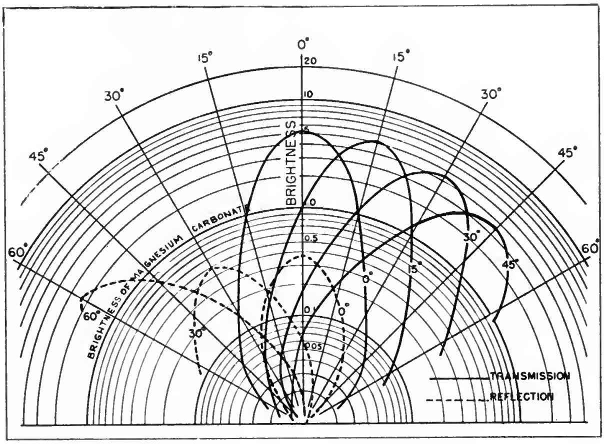


Fig. 13. Emulsion on black glass.

cept by the artificial expedient of placing two noncontiguous samples of the screen side by side under the same ambient illumination, one being highlighted by projection, the other representing shadow brightness. A continuous sample of the screen appears to be completely transilluminated over a large area around each highlight. The rule apparently applicable here is that the low-contrast factors (the halation) predominate over the high-contrast factor (the favorable photometric values) which means, as we stated before, that before a careful photometric evaluation is possible and meaningful, we must have a screen reasonably free from other disqualifying characteristics.

The next two figures illustrate some of the characteristics of a molded plastic fresnel lens type of screen. The sample supplied to us was intended for television projection. One side of this screen is formed of fine concentric prismatic rings in a typical fresnel lens arrangement. The other side is provided with a fine ribbed structure which imparts an asymmetric scattering characteristic to the screen which is properly intended to enhance the horizontal distribution

Fig. 14. Molded Fresnel lens type screen; measurements in horizontal plane through center.

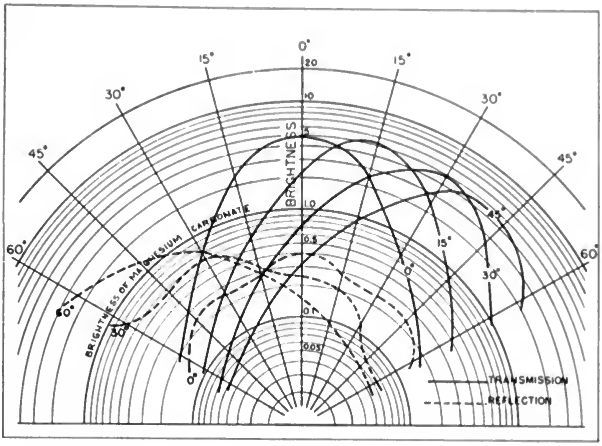
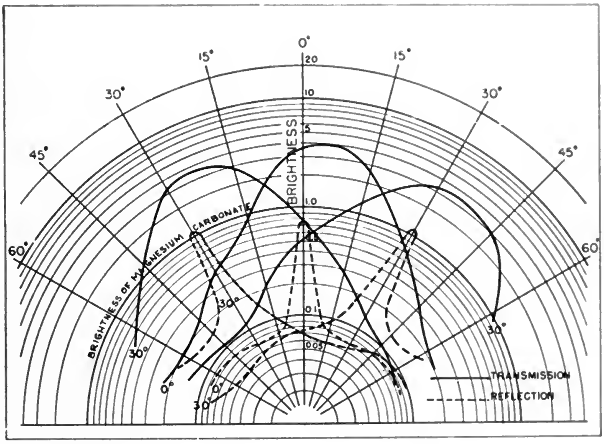


Fig. 15. Molded Fresnel lens type screen; measurements in vertical plane near edge.



at the expense of the vertical distribution, as well as to conceal the ring structure. Figure 14 represents measurements taken at the optical center of this screen along a horizontal meridian, with the ribbed structure vertical. The transmissive brightness curves are surprisingly regular and almost identical with those of some of the screens previously shown. The reflective brightness curves indicate a considerable amount of specular reflection which is observable particularly at large angles of incidence. Figure 15 represents measurements taken near the edge of the same screen along a vertical meridian. The directive effect of the fresnel structure is clearly evident in the three transmission curves illustrated, as a displacement of approximately 7° toward the optical center of the screen at all angles of incidence. This displacement is not, however, evident in the reflection curves because reflection occurs principally off of the ribbed side of the screen. The very pronounced specular reflection exhibited is the result of longitudinal cylindrical reflection from the ribbed surface of the screen when the longitudinal axis of the ribs is in the viewing

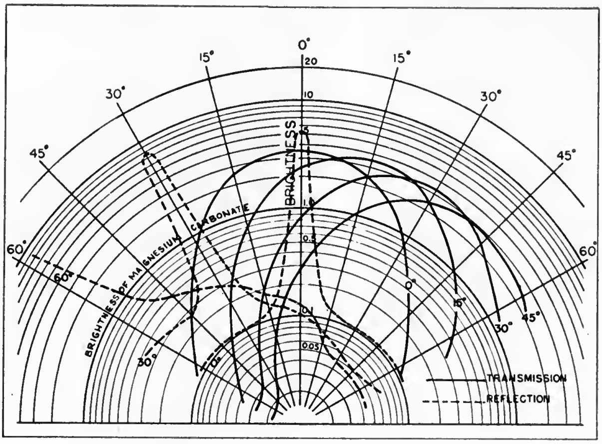


Fig. 16. Antireflection coated opal glass screen.

meridian. The photometric performance of this screen is not particularly impressive as compared to simpler types of rear-projection screens, but the possibilities inherent in controlled asymmetric diffusion, made use of to some extent in this screen, are suggestive.

Figure 16 illustrates the performance of a sample rear-projection screen made available to us and consisting of what appears to be an antireflection coated flashed opal glass sandwich. This screen is characterized by an unusually large and broad transmissive brightness distribution and a very low reflectance of almost cosine law distribution except at specular angles, at which points the gloss, despite the antireflection coating, is very pronounced. This screen would be very desirable for its photometric properties but unfortunately, the high contrast implied by the data is vitiated by the excessive halation and transillumination through the thick opal glass sandwich. The resolution of this screen at angles other than the normal viewing angle rapidly deteriorates because of the depth of the diffusing layer.

In the above description of some of the many rear-projection screens we have been permitted to examine we have only briefly alluded to the comparative merits of the screens. We all know, of course, that there is no such thing as a "best" screen. We can only seek the best screen for any given application. Some theaters require a matte screen with almost cosine law distribution; other houses are very narrow and benefit from the greater brightness realizable from screens having a narrower distribution angle. Photometrically the best screen for any given application would appear to be the one having a uniform brightness distribution over only the required viewing angle. The vertical viewing angle of such a screen would desirably be less than the horizontal one. Such a screen would also inherently tend to be the brightest screen for the application. Naturally, no screen can be found which will have uniform brightness over a specified distribution angle and then fall off rapidly to zero brightness. However, it is not beyond the bounds of possibility that a screen will yet be tailor-made to meet such specifications. The extent to which a screen departs from these conditions determines its departure from maximum efficiency, but specifications governing this fall within the province of standards committees. We shall concern ourselves only with what has been done and with what can be done.

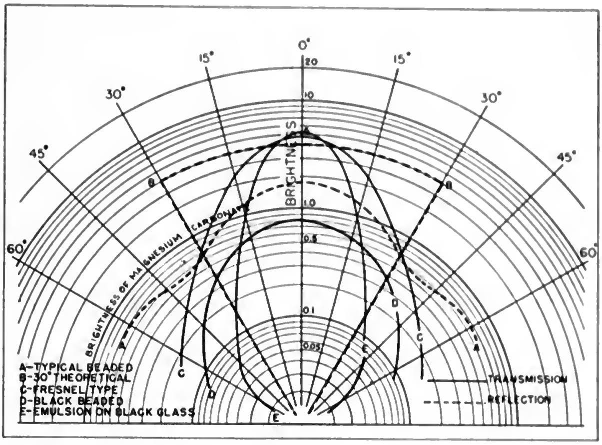


Fig. 17. Comparison of typical rear-projection screen with a beaded screen and with a hypothetical screen of 100% efficiency over a 30° angle of view.

Figure 17 gives comparative brightness curves, taken at normal projection incidence, for three of the better rear-projection screens whose complete curves have already been shown. In order to provide a basis for the comparison there are also included curves for a typical beaded screen and for a hypothetical screen of 100% efficiency whose theoretical distribution is confined to 30° from the normal.

These curves reveal some interesting facts. With the exception of screen (D) (black beaded) none of the rear-projection screens, and this is true as well of screens not included in Fig. 17, have as good a brightness distribution or freedom from "hot spot" as the ordinary beaded screen, yet beaded screens are known for their marked directional distribution. The only screen free from an objectionable "hot spot" is screen (D) which is very inferior in brightness. If these screens are now compared with the theoretical possibilities held forth by curve (B) it will at once be apparent how far we have yet to go in the direction of a really good rear-projection screen.

In order to illustrate the possibilities inherent in controlled brightness distribution we have for Fig. 18 drawn curves similar to curve (B) of the previous figure to illustrate the brightness of screens whose possible theoretical brightness has been computed mathematically by evaluating the surface integral of the light intensity function of a Lambert-type diffuser of various specified symmetrical and asymmetrical distribution patterns. Curve (A), for the purpose of comparison, is that of a typical beaded screen. It should be noted that these curves are divided into vertical and horizontal quadrants, and that curve (A) is of course symmetrical through both quadrants. Curves (B) and (C) are for hypothetical screens whose distribution is confined to 45° and 30° from the normal, respectively. These screens, despite their specified uniform brightness over the entire specified distribution angle, would be two and four times as bright as a standard cosine law diffuser. If, as is clearly indicated in most projection situations, the vertical distribution be limited, even greater brightness gains could be achieved. Curves (D), (E) and (F) are for hypothetical screens whose horizontal distribution is confined to 45°, 45° and 40°, respectively, to each side of the vertical meridian, and whose vertical distribution is confined to $22\frac{1}{2}$°, 15° and $12\frac{1}{2}$°, respectively, above and below the horizontal meridian. In

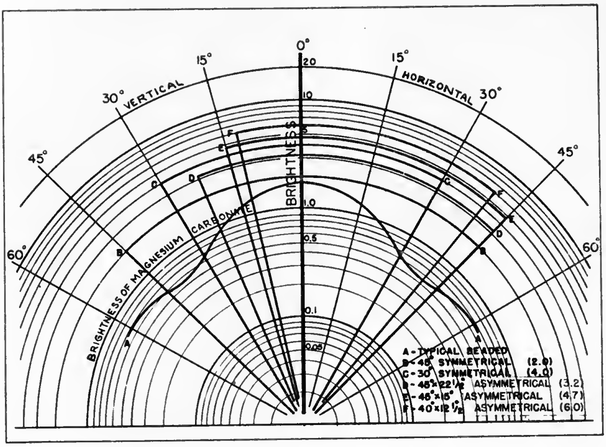


Fig. 18. Curves illustrating the theoretical brightness gains of engineered screens of variously assigned angles of view.

other words, they have a rectangular distribution pattern. These screens could attain the astonishing brightness of, respectively, 3.2, 4.7 and 6.0 times the brightness of the standard without fall-off from or hot-spot at the center.

Returning now to the problem of an objective evaluation of rear-projection screens, we have shown that a single term such as "brightness gain" does not convey sufficient information. It may indeed misinform because it is the result of measurement at a singular point, the hot-spot. Two screens might have the same brightness characteristics at all viewing angles except that one has a narrow hot-spot at the normal viewing angle, and yet they would be rated as being very different in effective brightness gain. The curves of reflected and transmitted brightness do give complete and objective photometric information, but they require some analysis and a bit of experience in their application. A single curve, which would be representative of the performance of the screen under actual viewing conditions, and from which such information as the available contrast range, the presence of hot-spots, the existence of gloss or specular reflection and the amount of tolerable ambient illumination can be ascertained by inspection, would be most desirable for objective photometric evaluation.

Figure 19 illustrates a projection arrangement for front or rear projection in which the projection angle and the viewing angle are maintained equal, and in which ambient light is assumed to fall upon the screen at an angle of 30°. This is an arbitrary arrangement, yet it will be seen to be not untypical of actual rear-projection conditions. The justification for this selection is the fact that the photometric factors involved change only gradually and without marked singularities so that the behavior of a screen in any arbitrary arrangement is representative of its behavior within a considerable range from the arbitrary arrangement selected.

Using the measurements made upon the screens previously discussed we have computed the transmissive or reflective brightness ratios for the corresponding projection and viewing angles illustrated in the diagram, and the reflective brightness ratios for the corresponding viewing angles at 30° left ambient light incidence. The total brightness of the screen as viewed at any designated angle is then equal to the sum of the projected and ambient brightness. This is the maximum attainable highlight brightness. The brightness of the screen at any

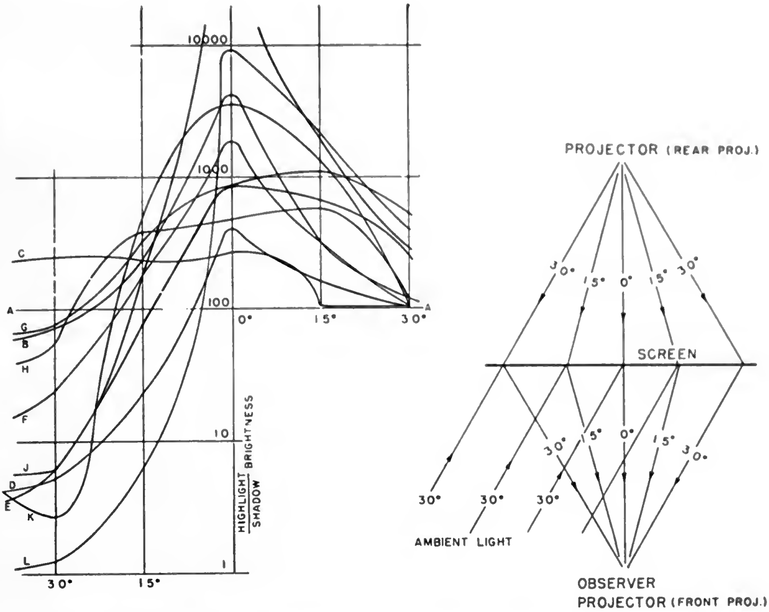


Fig. 19. Contrast profiles. The projection diagram illustrates the basis of the measurements from which the curves were calculated.

viewing angle due to the ambient illumination alone is equal to the minimum shadow brightness. The quotient of the maximum highlight brightness divided by the minimum shadow brightness represents the maximum picture contrast range available, regardless of the contrast of the print being projected. If the maximum available picture contrast is plotted versus the screen viewing angle, a curve results which we choose to call the "contrast profile." The contrast profile reveals a wealth of data regarding not only the available contrast at any point on the screen, but information as to singularities such as gloss or hot-spots.

The contrast profile is plotted on a logarithmic base. The contrast of a screen whose reflective and transmissive brightness ratios are equal is taken as 100. On this basis the line A-A at the 100 ordinate also represents a perfect cosine law screen because of the well-known fact that the reflectivity of cosine law diffusers is always equal at the same viewing angle, regardless of the incident projection angle. A little consideration will reveal that the contrast profile may be read to advantage in another manner. If the reference line A-A is designated as unity (1.0) instead of 100, then the values of the ordinate may be read as the ratio by which the ambient light upon the screen may be increased over that permissible upon a cosine law screen and yet maintain the same picture contrast. Thus the contrast profile of a screen which reads above 1000 or (10.0) at any point means that the screen at that point could be subjected to 10 times the ambient illumination of a perfect (cosine law) diffusing screen and still have as good or better picture contrast.

It is apparent that most of the contrast profiles show peaks at the normal viewing angle. These peaks are simply the result of the increase in the numerator of the contrast ratio fraction, caused by the high direct transmission or hot-spot brightness at the normal viewing angle. The size of the peaks is a measure of the severity of the hot-spot, and a ratio between the ordinate heights of the hot-spot peaks, which is easily found because of the logarithmic plot, permits of a quick realistic comparison.

Most of the screens exhibit a marked contrast profile drop in the vicinity of 30° left viewing angle, which is a symptom of the specular reflection of the 30° incident ambient light. It is characteristic of most rear-projection screens that they are worse than front-projection screens in this respect. A desirable rule to follow in rear projection is therefore to avoid the incidence of ambient light at angles within the specular range.

Adverting briefly to the individual contrast profiles, the letters identify screens according to the following description:

A. Cosine law diffuser, Fig. 4
B. Plastic rear projection, Fig. 8
C. Beaded front projection, Fig. 7
D. Aluminized stereo projection, Fig. 6
E. Emulsion on black glass, rear projection, Fig. 13
F. Fresnel type, rear projection, Fig. 14
G. Black beaded coating on glass, rear projection, Fig. 10
H. Plastic black, rear projection, Fig. 9
J. Emulsion on opal glass, rear projection, Fig. 12
K. Anti-reflection coated opal glass, rear projection, Fig. 16
L. Dark black beaded coating on plastic, rear projection, Fig. 11

A few of the curves are of especial interest as illustrations of the properties of the screens they describe.

Curve C illustrates the excellent contrast under ambient illumination realizable with beaded reflecting screens. That this is the result of the unique directive properties of beaded screens is proved by the anomalous contrast low from 15° to 30° right viewing angle, with no low point at all due to ordinary specular ambient light reflection at 30° left viewing angle.

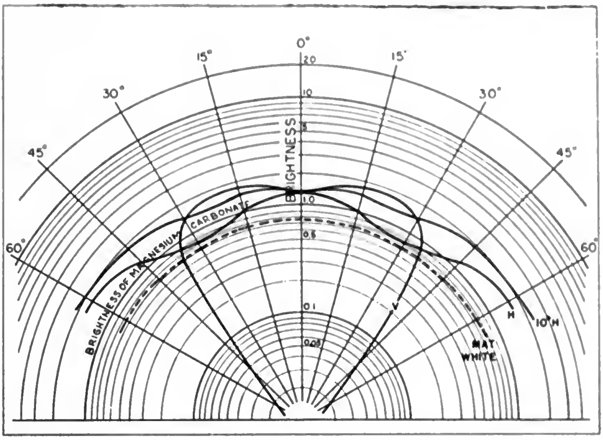
Curve H, a black plastic rear-projection screen, is an example of a good rear-projection screen with moderately high contrast over a wide viewing angle range, and with relatively low specular reflection of ambient light.

Curves K and L are examples of screens whose contrast profile takes an extremely sharp dip as a result of the bad gloss of the screen.

We have presented numerous data on existing screens and we have alluded to the possibilities latent in screens engineered to conform to certain restrictions on the viewing angle, with particular reference to asymmetric light distribution favoring the horizontal viewing angle at the expense of the vertical. We shall now describe some preliminary work done to realize these possibilities, based on earlier work by one of the authors[10] on screens having asymmetric brightness distribution.

Our experimental work on screens is based on the following premises. Most screens depend on random refractive or reflective scattering of light by microscopic granules or surface irregularities, and their brightness curves can be regarded as optical probability curves. In order to obtain controlled diffusion it is necessary to secure, not random scattering, but controlled direction of the projected light. In other words, the optical performance of the screen must be the result of deliberate design and computation, much as lens systems are the result of design and computation. We propose that the screen be treated as an optical instrument, not as a random scatterer of light rays, and we feel that in this direction is possible the greatest advance in screen development. Needless to say, only a complete goniophotometric specification of such a screen will specify its desirable properties, for no single term such as brightness gain

Fig. 20. Experimental outdoor theater screen curves taken in the vertical, horizontal and 10° off horizontal plane.



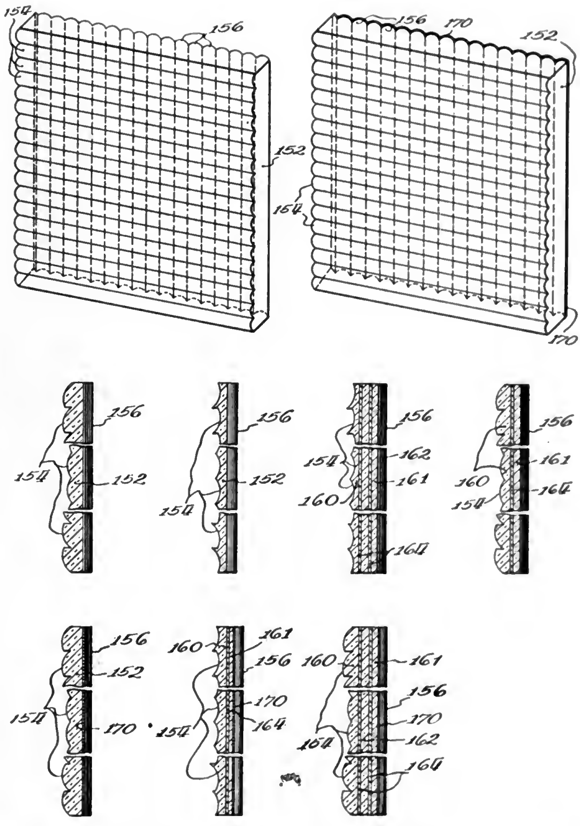


Fig. 21. Optically engineered screens as disclosed in Lessman Patent No. 2,326,042 (1943).

nor any single coefficient designating its general departure from cosine law distribution can designate such controlled asymmetric diffusion.

The performance of an experimental screen made up from available materials without the benefit of refined design is illustrated in Fig. 20. The resolution of this screen, due to the large size of the diffusing elements, makes it suitable only for large projections such as outdoor theater screens, but the brightness gains realized confirm the soundness of the approach employed.

The curves are shown compared to the brightness of one of the best matte white screens obtainable. The brightness of the screen in the horizontal meridian and along a 10° off horizontal meridian is about 250% greater than the matte white screen all the way out to 60° from the normal viewing angle. The brightness along the vertical meridian is maintained at about 250% of the comparison screen out to 30° from the normal viewing angle and then falls off sharply almost to zero. These brightness gains are startling yet they can be bettered by properly designing this screen for the more limited horizontal angle desirable for this application.

The structure of this screen is illustrated in Fig. 21. The experimental screen consists of a piece of glass ribbed horizontally on the front face and ribbed vertically and silvered on the rear face. The curvature of the ribs is the design factor controlling the horizontal and vertical diffusion, and since the path of the projected light rays incident on the screen can be computed through the several refractions and reflections involved, the performance of the screen, like that of any other optical instrument, is completely predetermined.

References

1. Whiteness of Projection Screens, American War Standard Z52.45-1945.
2. Brightness Characteristics of Projection Screens, American War Standard Z52.46-1945.
3. France B. Berger, "Characteristics of motion picture and television screens," *Jour. SMPTE, 55:* 131–46, Aug. 1950.
4. Loyd A. Jones and Milton F. Fillius, "Reflection characteristics of projection screens," *Trans. SMPE No. 11:* 59–73, 1920.
5. Loyd A. Jones and C. Tuttle, "Reflection characteristics of projection screens," *Trans. SMPE, No. 28:* 183–195, Feb. 1927.
6. W. F. Little, "Tests of motion picture screens," *Jour. SMPE, 16:* 31–37, Jan. 1931.
7. Francis M. Falge, "Motion picture screens—their selection and use for best picture presentation," *Jour. SMPE, 17:* 343–362, Sept. 1931.
8. Report of the Projection Screens Committee, *Jour. SMPE, 17:* 437–448, Sept. 1931.
9. Screen Viewing Factors Symposium, *Jour. SMPTE, 57:* 185–246, Sept. 1951.
10. Gerhard Lessman, U.S. Pat. 2,326,042, Aug. 3, 1943.

An Apparatus for Aperture-Response Testing of Large Schmidt-Type Projection Optical Systems

By D. J. PARKER, S. W. JOHNSON and L. T. SACHTLEBEN

An interpretation of the aperture-response concept as it applies to lenses or optical systems is followed by a description of an apparatus with which large Schmidt-type projection optical systems may be tested. The apparatus is adapted to present continuously the response curve on an oscilloscope, where it may be photographed against a grid for further study. The optical system may be tested for response to both radial and tangential line detail, in field zones that extend out to half the normal raster diagonal from the center.

THE PROBLEM of measuring the ability of a lens or optical system to produce a good image is an old one. Evaluations have generally been based on the ability of the lens to produce an image of fine parallel line detail. The means employed have usually consisted of observing the image at high magnification with a microscope, or of photographing the lines on a sensitive emulsion. In either case, quantitative evaluation of the performance of the lens has been limited to determining the number of lines per millimeter in the image surface at which the lens failed to produce anything that could be recognized as an image of the lines.[1] This method describes the condition under which the lens completely fails to perform, and quite obviously yields little or no quantitative information about the performance of the lens in its normal range of usefulness. This was often made clearly evident by the fact that although the limiting resolution of a particular lens might be many lines per millimeter, the image would remain "soft" and of poor contrast even down to a very few lines per millimeter. In the case of some other lens, the limit of resolution might not extend out to nearly so many lines per millimeter, but below that figure, the lens might rapidly attain performance of very acceptable quality.

No new or very effective methods were brought to bear upon this problem until the late 1940's, when the papers of Herriott[2] and Schade[3] appeared.

These papers recognized that a lens

Presented on October 7, 1953, at the Society's Convention at New York, by D. J. Parker, S. W. Johnson and L. T. Sachtleben, Radio Corporation of America, RCA Victor Div., Engineering Products Dept., Camden 2, N. J.
(This paper was received October 7, 1953.)

could be evaluated by making a survey of the distribution of light in the image of the parallel line test object. If the parallel line test object has a constant contrast ratio over a large range of line widths, such a survey will provide information about any failure of contrast to remain constant in the image when line width changes, as a result of departures of lens imagery from geometrical perfection. This information is independent of any uniform stray light that the lens may originate and deliver to the plane of the image, because such stray light has only the *effect* of a change of contrast in all parts of the object by a fixed amount, and does not disturb the essential property of constancy of the contrast ratio throughout all parts of the test object.

Herriott and Schade accomplished such surveys experimentally by what amounted to passing a relatively small scanning aperture across the image of the lines and measuring the light that came through the aperture as a function of its position in the image. The ratio of the difference between maximum and minimum light passed by the aperture for one width of line to the difference for another width of line, with certain qualifying restrictions to be mentioned in a paragraph below, gives a number that is characteristic of the image-forming properties of the lines insofar as those two particular line widths are concerned. These image-forming properties are determined by the distribution of light in the image which the lens forms of an ideal point object. This distribution is, in general, symmetrical about ideal geometrical image points lying near the axis of the lens, and extends out from the ideal image point to where illuminance gradients cease to exist and uniform stray illuminance, if any, begins. Such a distribution of light constitutes the physical image.

In Schade's work, the differences described above are called the "aperture response" of the lens for the particular line widths involved. The aperture response generally decreases as line width decreases and approaches a maximum as line width becomes indefinitely increased. A curve that shows aperture response, at all line widths, as a fraction or percentage of this maximum is called the aperture-response characteristic of the lens under consideration. As noted above, the aperture response characteristic of the lens tells nothing about the general stray light that may arise in the lens. It cannot, therefore, tell the whole story of lens performance. It does, however, show the performance of the lens insofar as it is dependent upon the size of the physical image and the distribution of light in the physical image.

The causes of any general or uniform stray light contributed by the lens, may or may not affect the aperture response, accordingly as they do or do not contribute to determining the size and distribution of light in the physical image. It may be said, in general, that if the aperture response of a lens falls off very rapidly due to properties of the lens that do not contribute to uniform stray light, the lens is fundamentally faulty in design or construction. If aperture response is good, but stray light is high, removal of the stray light by coating or by eliminating mounting reflections, will surely improve the lens. Should poor aperture response be largely due to the factors that originate the stray light, such as poor surface polish which introduces diffraction defects in the imagery, their removal should greatly improve the lens.

Apart from the quality of the design and construction of the lens itself, the shape of the aperture response curve is dependent upon two conditions external to the lens. The first of these is the distribution of luminance in the lines of the test pattern, and the second is the particular focal plane in which the aperture-response measurements are made. If the distribution of luminance in the lines of the test object is sinusoidal, a so-called sine-wave aperture-response curve for the lens will result. This curve is especially useful in the overall evaluation of the performance of electrooptical systems for the reason that analogous aperture-response curves of the sine-wave variety can be measured or otherwise determined for every element in the system even including the human eye, and when these are all multiplied together in the proper manner, a curve is obtained that evaluates the quality of the image seen by the observer. From this curve, the adequacy of the overall system may be judged. The effect upon this curve of any changes in the sine-wave aperture response of the optical system, or for that matter, of any other element in the overall system, may be judged readily, and its importance evaluated at any stage in the development of the overall system.

The relative aperture response at two different line widths is dependent upon the selected plane of focus. For example, if an optical system is focused to obtain its maximum response for relatively coarse detail, it is, in general, necessary to refocus it to obtain its maximum response for relatively fine detail. This suggests at once that the so-called "best focus" will, in general, always be a compromise that must be judged by the operator, and that his judgment of the best compromise will depend upon the character of the subject and the elements and qualities in it which the operator wishes to emphasize. This relative variation of response with focus tends to diminish as the lens approaches more closely to ideal perfection.

The design and construction of a lens directly determine the distribution of light in the image that it forms of an ideal object point. It also determines the way in which this distribution varies with focus. From the practical point of view, the "image" of an ideal object point is the physical spot of light at a selected plane of focus. The distribution of light in this spot determines the shape of the sine-wave aperture-response curve of the lens for this plane of focus.

The measurement work involved in obtaining the aperture-response curve of a lens can be simplified by using a square-wave pattern of uniformly black and uniformly white lines as a test object, and measuring average square-wave aperture response, rather than peak-to-peak square-wave aperture response. This averaging process takes into account the change in shape of the waveform preceding decrease in peak-to-peak amplitude. For practical purposes, the resulting average square-wave aperture-response curve may be converted to the corresponding sine-wave aperture-response curve. The apparatus described in this paper determines the sine-wave aperture response of a Schmidt optical system in this manner.

Figure 1 illustrates the general arrangement of the testing setup. At the right is the conventional Schmidt optical system including spherical mirror and corrector or ogee lens. Spaced from it at the left, at the distance at which the Schmidt system is designed to project a television picture, is the apparatus for introducing the square-wave test signals into the optical system. This signal generator consists of a projection lamp and optical system arranged to illuminate uniformly the ogee lens of the Schmidt optical system. The lamp and lens X of the optical system uniformly illuminate the projection lenses Y and Z, which, in turn, project lens X upon the ogee lens. The lamp and lenses are located inside a cylindrical drum with the lenses Y and Z very close to the drum in order to illuminate a limited part of the drum uniformly. This drum is rotated by a synchronous motor at 1800 rpm. The periphery of the drum is perforated with a series of groups of slots. Each pair of slots in any group is separated by an opaque bar

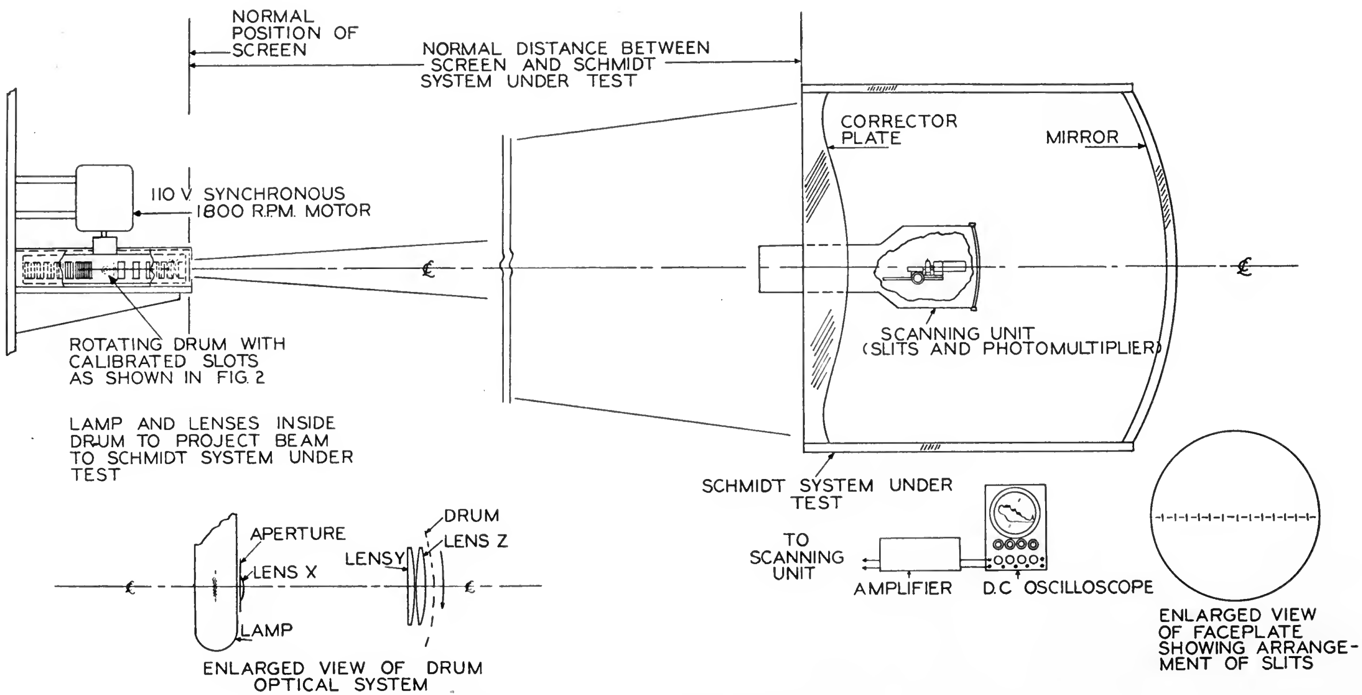


Fig. 1. Schematic of aperture-response measuring setup.

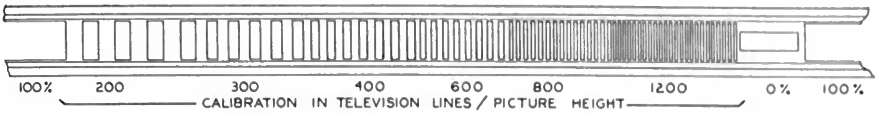


Fig. 2. Developed view of slotted periphery of scanning drum.

whose width equals the width of the slot. The slots range in width from 0.9–0.15 in. which respectively correspond to 200 television lines per picture height and 1200 lines per picture height for a 15-ft high picture. Six groups of slots are employed corresponding to 200, 300, 400, 600, 800 and 1200 television lines per picture height. Figure 2 is a developed view of the slotted surface of this drum. In addition to the groups of slots, a portion of the periphery is perforated with a long unbarred slot to provide a 100% response reference level, while another section is similarly perforated to provide a zero response reference level.

The 750-w bi-plane projection lamp used to illuminate the slots is cooled with a fan. The optical system, fan, slotted drum and synchronous motor are adjustably mounted so that the rotation axis may be located in either a horizontal or a vertical plane. The assembly may also be tilted to project the light beam horizontally or upward at a convenient angle. The drum assembly is turret-mounted on top of a cabinet which rolls on casters and may be set astride a guide rail fastened to the floor of the test room. By moving the drum assembly along the guide rail and reorienting the turret to keep the beam of light projected into the Schmidt, the performance of the optical system may be tested at any zone of its normal field. By setting the drum axis in a horizontal and then in a vertical plane, performance difference due to astigmatism may be observed in the outlying parts of the field. The signal generator assembly is shown in Fig. 3.

Referring once more to Fig. 1, the kinescope in the Schmidt optical system on the right is replaced by an opaque kinescope faceplate that is provided with a series of very narrow transparent slits, arranged along the diameter of its concave surface. These slits are arranged alternately in horizontal and vertical positions. The face plate is secured to the end of a mechanical assembly that is mounted in the optical system in the normal position of the kinescope. This assembly mounts a multiplier phototube and a mechanism for positioning the phototube behind any slit on the faceplate. The faceplate and phototube assembly are shown in Fig. 4, and this assembly is shown mounted in operating position in the Schmidt optical system in Fig. 5.

By the principle of optical reversibility, the slots in the spinning drum are focused by the Schmidt optical system on the concave surface of the faceplate. By suitably orienting and positioning all of the elements concerned, the slots may be imaged upon the central slit of the group or upon any slit in the outlying part of the field of the optical system. The images of the slots move at right angles to their long edges which must be set parallel to the slit. Several drum slots are imaged simultaneously in the vicinity of the slit and the relative motion between this image and the slit enables the slit to function as a scanning aperture to survey the distribution of light in the image. If the slits are distributed along a horizontal diameter of the faceplate, measurements made with the series of vertical slits will then give a series of aperture-response curves for the tangential image surface of the optical system. If the scanning is done with the horizontal slits, the resulting

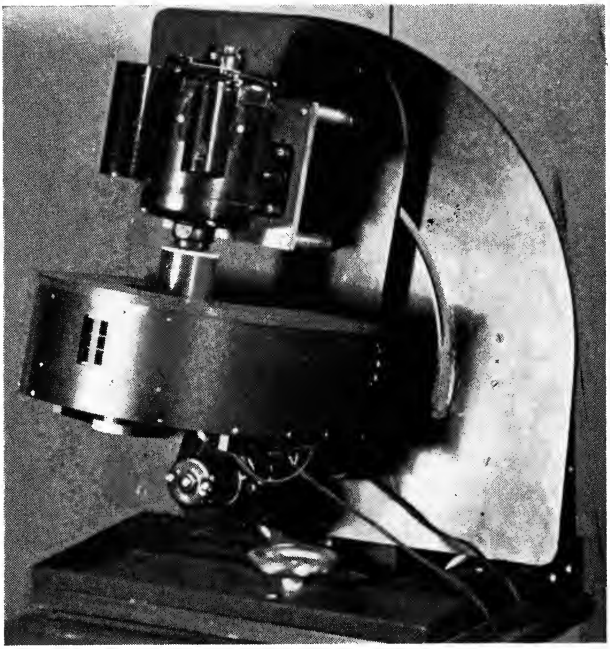


Fig. 3. Signal generator assembly.

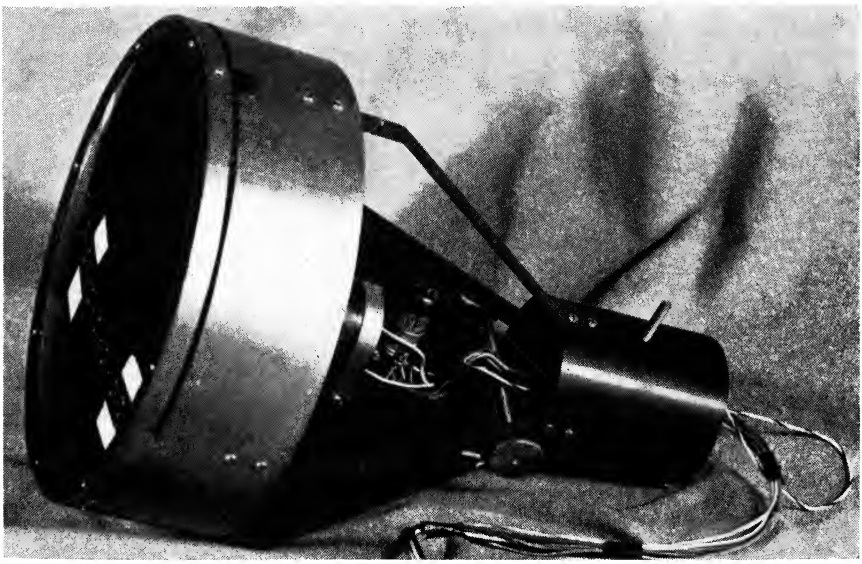


Fig. 4. Faceplate and phototube assembly.

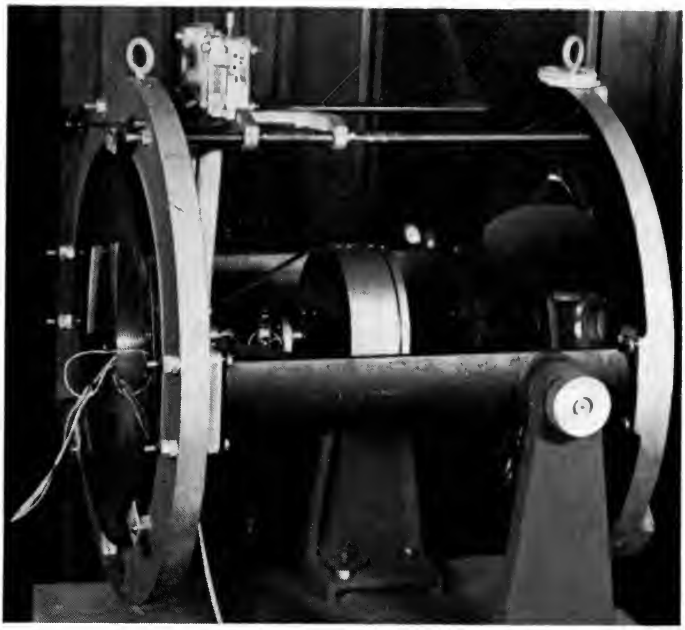


Fig. 5. Faceplate and phototube assembly mounted in operating position in the optical system.

response curves will apply to the sagittal image surface of the system.

The slits are about $\frac{1}{1000}$ of an inch wide and are a little longer than the images of the slots. The slits can receive light from the entire effective aperture of the optical system, and no other optics that might introduce effects of their own are involved in the tests. A number 5819 multiplier phototube is used as a photo-receptor and is provided with a battery power supply. Figure 6 shows the electrical circuit of the measuring system. The output of the phototube is coupled by a cathode follower tube to an amplifier with a flat response over a frequency range exceeding the 10th harmonic of the fundamental frequency corresponding to 1200 lines per picture height. The amplifier output is rectified to provide a voltage that is proportional to the average d-c value of the light pulses that are passed by the slit. The smaller unbarred slot passes half as much light to the slit as any of the slots in the barred section of the drum. When this single-pulse of relatively low frequency is impressed on the electrical circuit, it develops the same d-c voltage at its output terminals that would be developed by a barred section of the drum if the bars were so fine that they would not produce any variations in light passing the slit, due to a total loss of contrast in the image. This determines an output voltage that corresponds to zero square-wave aperture response. The larger unbarred section of the drum passes twice as much light to the slit, or an amount equal to that passed to the slit by any slot in the barred section of the drum. This develops voltage at the electrical circuit output that equals the voltage that would be developed by the barred sections of the

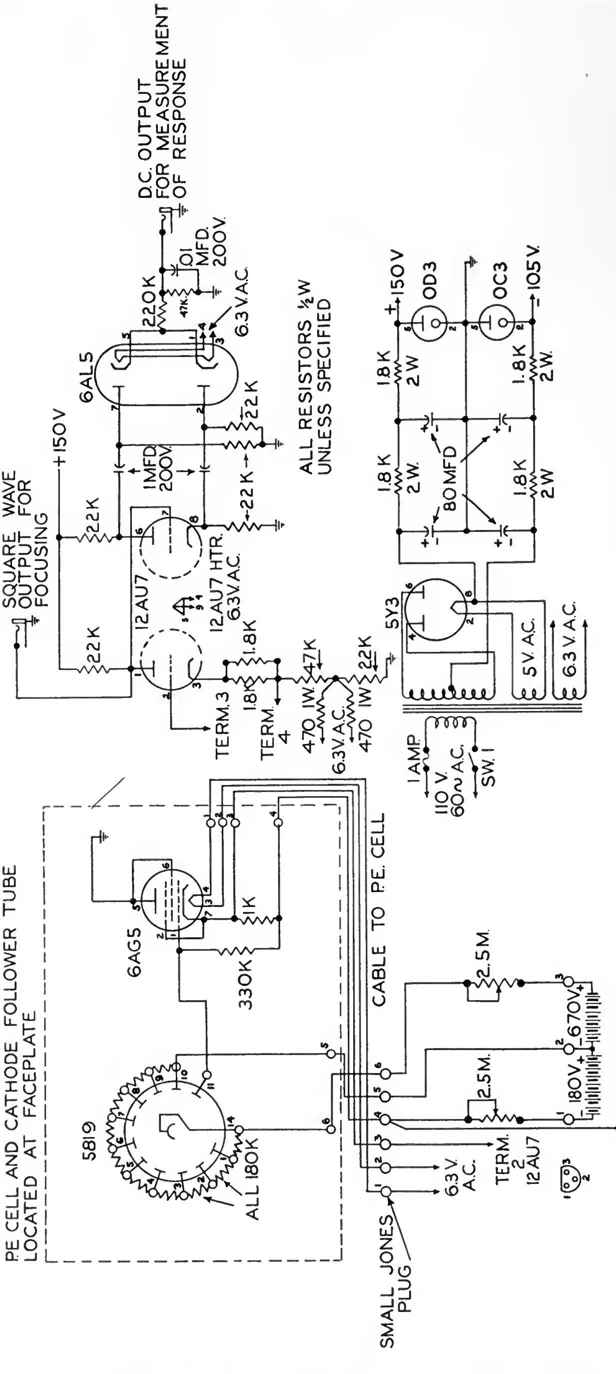


Fig. 6. Electrical circuit of the aperture-response measuring system.

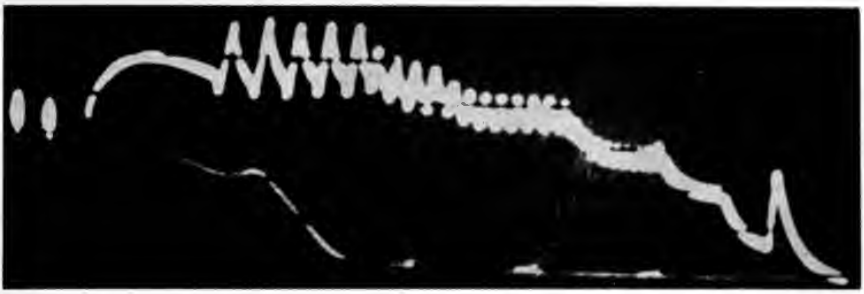


Fig. 7. Aperture-response curve as it appears on the oscilloscope.

drum were the optical system capable of producing a perfect image. This voltage is then the 100% square-wave aperture-response reference.

The output voltages developed during the passage of the various sections of the drum are impressed upon a d-c oscilloscope whose horizontal sweep is synchronized to the same frequency that drives the synchronous drum motor. A stationary trace is developed on the face of the oscilloscope in the form of a series of steps whose distances above the zero response level are proportional to the square-wave aperture response at the various numbers of television lines per picture height that correspond to the groups of slots in the drum. An edge-lighted grid may be placed in front of the oscilloscope and both grid and response trace photographed for later evaluation of the results. The combined spectral response of the 5819 multiplier phototube and the tungsten light emission gives a sensitivity curve that extends from 3800 A to 6500 A, peaked at about 5200 A. This reasonably approximates visual response for the purpose of evaluating image quality in a projection optical system of this type. It has been found advisable to place an infrared absorbing filter in the light beam near the rotating drum to protect the slits from damage due to heating. The cooling fan normally used to direct air through the central aperture of the spherical mirror is also used for this purpose. Light is delivered to the slits by the optical system at about $f/0.85$ and rather high temperatures can be developed locally in the neighborhood of the slits.

Figure 7 is a photograph of one of the response curves on the face of the oscilloscope. When the sine-wave aperture-response curve is derived from the data furnished by this curve, the result is in reasonably good agreement with a similar response curve computed from measurements made on the distribution of light in the projected image of a very small light source located at the concave surface of the kinescope faceplate. A figure of merit may be derived from the sine-wave aperture response curve if a square topped curve is plotted having 100% response at all line numbers and extending out far enough to include the same area that is included under the squared sine-wave aperture-response curve. The figure of merit (N_e, or equivalent pass-band, in Schade's[4] terminology) is the line number at cutoff for this derived curve.

References

1. Irvine C. Gardner, "A test of lens resolution for the photographer," NBS Cir. C428, U.S. Dept. Commerce, Dec. 27, 1940.
2. W. Herriott, "A photoelectric lens bench," *J. Opt. Soc. Am., 37:* 472–474, Mar. 1947.
3. Otto H. Schade, "Electro-optical char-

acteristics of television systems: Introduction," *RCA Rev. 9:* 5–13, Mar. 1948.
"Part I—Characteristics of vision and visual systems," *ibid.*, 13–37, Mar. 1948.
"Part II—Electro-optical specifications for television systems," *ibid.*, 245–286, June 1948.
"Part III—Electro-optical characteristics of camera systems," *ibid.*, 490–530, Sept. 1948.
"Part IV—Correlation and evaluation of electro-optical characteristics of imaging systems," *ibid.*, 653–686, Dec. 1948.

4. Otto H. Schade, "Image gradation, graininess and sharpness in television and motion picture systems; Part II: The grain structure of motion picture images—an analysis of deviations and fluctuations of the sample number," *Jour. SMPTE, 58:* 181–222, Mar. 1952.

Compact High-Output Engine-Generator Set for Lighting Motion-Picture and TV Locations

By M. A. HANKINS and PETER MOLE

Since the earliest use of artificial light on motion-picture locations, portable engine-driven lighting-power sources have been needed. This paper describes the design features and performance characteristics of a new 650-amp, 120-v, d-c, engine-generator set which is much smaller and lighter in proportion to its power output than any of the previous equipments.

IN THE DESIGN of engine-generator equipment for supplying power on locations many factors must be judiciously considered in order to provide adequate "efficiency of utilization." Of prime importance is the balance of maximum power vs. flexibility and portability.

As an example, a single 150-kw plant,[1] now widely used in the industry, will satisfy the overall power requirements for most locations. The Mole-1400[2] is such a plant but, although it is more portable than any other of equal capacity, it is 118 in. long × 54 in. wide × 73 in. high and weighs 11,660 lb. The trend toward an increase in the amount of work at remote locations has resulted in the need for more portable and flexible units to supplement the comparatively larger types.

A considerable handling and transportation advantage would result if power capacity equivalent to the single 150-kw plant could be produced by two smaller packages with a combined weight appreciably below that of the larger single unit. The smaller plants could be loaded on or trailed behind the equipment trucks, or even be carried by the same truck upon which lighting equipment is mounted during operation. In emergencies a plant of sufficiently small dimensions and weight may be transported to location by air.

By utilizing two smaller units electrically connected for 3-wire distribution, a saving of 30% in cable is effected over the 2-wire system of the larger plant.

The larger plant is at times operated at no more than half capacity on locations where full capacity is required only for peek demand. If two smaller plants were employed only one need be operated during the slack periods.

A shut-down of the larger plant, when it is the sole source of power, may bring production to a standstill, whereas, if two smaller units are operating and one of them requires attention it may be

Presented on October 9, 1953, at the Society's Convention at New York, by M. A. Hankins and Peter Mole (who read the paper), Mole-Richardson Co., 937 N. Sycamore Ave., Hollywood 38, Calif.
(This paper was received October 1, 1953.)

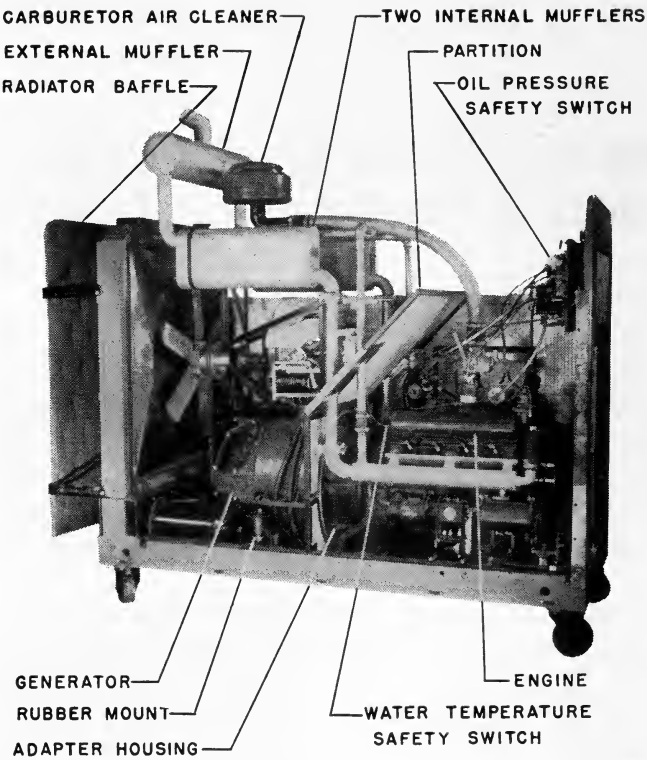


Fig. 1. The Mole-700 Engine-Generator, right side, with top and side removed.

possible to rearrange production so work can be continued with one machine.

After lengthy discussions with those in the industry who use the equipment, the Mole-Richardson Co. proceeded with the development of a compact, extremely portable power plant having about half the capacity of the Mole-1400 unit.

Since the prime objective was the reduction of size and weight as compared to previous designs, a survey was conducted to determine the maximum, practical operating speed for both engine and generator. This is doubly important because the weight per kilowatt of delivered power may be reduced as the rotating speed is increased.

It was learned that the General Electric Co. could produce a special d-c generator of the desired capacity with an operating speed as high as 3,600 rpm which is higher than normally encountered in d-c generator requipment of this capacity.

After a thorough study of the various types of available engines, the Cadillac automotive engine appeared to be the most promising. This choice was made after discussion of the engine's performance characteristics and the proposed application with Cadillac engineers in Detroit.

To verify the conclusions which had been reached, one engine was purchased and installed in an existing power plant in the Mole-Richardson Co.'s rental department. Its performance under actual

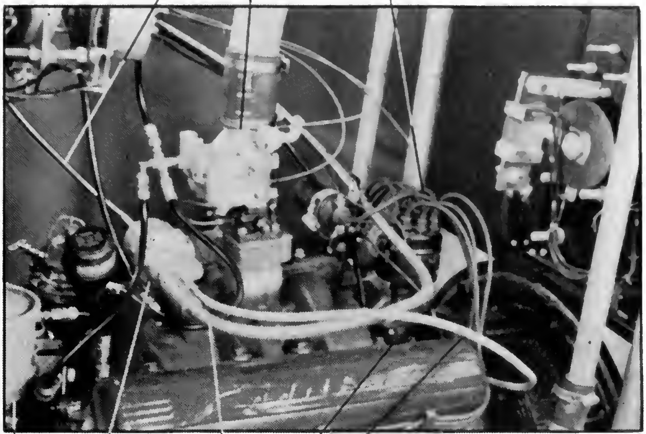


Fig. 2. Top of engine.

operating conditions was carefully studied for a period of eight months before deciding to proceed with the development.

The generator (Fig. 1) with performance matching the speed-horsepower characteristics of the Cadillac engine was developed through the combined efforts of General Electric and Mole-Richardson engineers. In the design, precautions were taken to provide more generator capacity than the Cadillac engine could mechanically deliver in order to prevent possible damage to the generator from overload.

It is a 2-wire generator rated at 650 amp, 125 v, d-c, for duty cycles normally encountered in location service. Its rated speed ranges from 2,800 to 3,200 rpm, which corresponds to a good operating region on the Cadillac speed-power curve. It is a single-bearing machine with class B insulation throughout. It is approximately flat compounded with the shunt field suitable for automatic voltage regulation. The weight of the generator is only 1,050 lb as compared to approximately 2,000 lb for commercially rated, lower-speed machines of equivalent capacity. The ripple voltage is less than $\frac{1}{2}$ of 1% of rated voltage, a feature which limits the emission of objectionable hum of arc lamps on the set.

The 8-cylinder, 90°, V-Type Cadillac engine is rated at 160 hp at 3,800 rpm and weighs 785 lb. For the first time this development permitted the use of an engine which is smaller and of less weight than the generator which it drives.

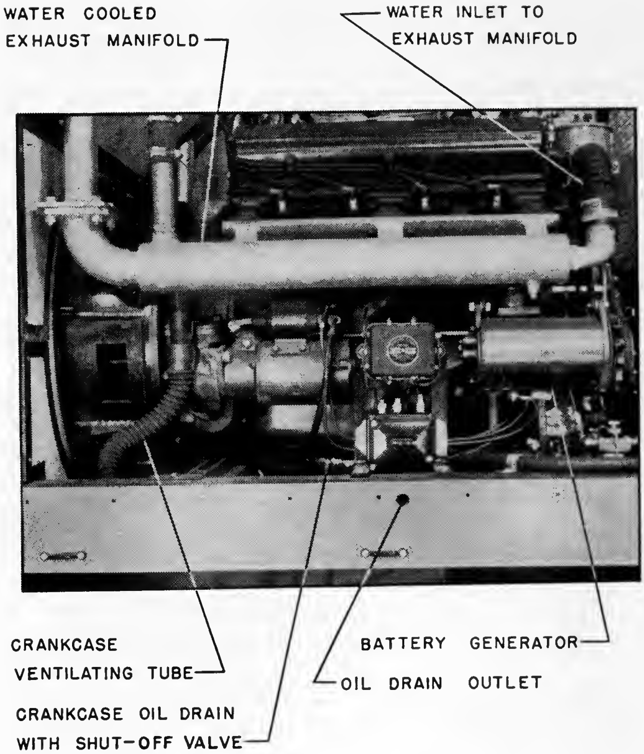


Fig. 3. Right side of engine.

Because there is no commercially available engine which can be applied to a motion-picture power plant without modification it was necessary to make the following revisions on the Cadillac motor:

1. Carburetor replaced by dual downdraft industrial type (Fig. 2).
2. Governor added to adjust and maintain speed.
3. Mechanical take-off device assembled beneath distributor for governor drive.
4. Oil filter added.
5. Exhaust manifold castings replaced by water-jacketed exhaust manifolds of Mole-Richardson design (Fig. 3).
6. Water-pump casting modified to divert cooling water through water-jacketed exhaust manifolds.
7. Battery generator relocated.
8. Oil drain line with shut-off valve installed.
9. Crankcase ventilating tube added for stationary application.
10. Electric fuel pump installed to assist mechanical fuel pump in maintaining adequate pressure at carburetor (Fig. 4).
11. Overspeed governor of Mole-Richardson design assembled on crankshaft to interrupt ignition circuit in the event of excess speed.
12. Fuel filter added.
13. Carburetor air cleaner relocated for access to cool air (Fig. 1).
14. Water temperature safety switch

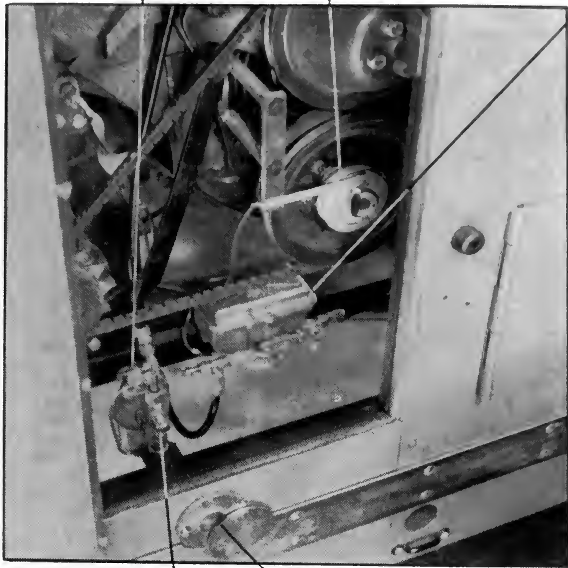


Fig. 4. Lower right front of engine.

installed in engine block to warn operator in the event of overheating.

15. Oil pressure safety switch added to interrupt ignition circuit should loss of oil pressure occur.

16. Hydra-matic flywheel replaced with standard type machined to accommodate generator coupling.

17. Engine fan removed.

One end of the armature of the single bearing generator is coupled to and supported by the engine flywheel. The coupling is of a flexible laminated steel-disk type with no deteriorating parts and has proven itself by application in other fields. A welded steel adapter housing (Fig. 1) was designed to mount the generator frame to the engine bell housing with rabbet fits to assure alignment of the axes of rotation of engine crankshaft and generator armature.

The engine and generator coupled together as an integral mechanical unit is supported on a welded steel box section main base frame by four rubber mountings to minimize transmission of vibrations to the base and enclosing structure.

The housing (Fig. 5) is made of fireproof materials throughout and designed for convenient operation and maintenance. It is constructed in sections: one end, two sides and one top for disassembly convenience at times of major overhaul. Five access doors are provided for routine inspection and maintenance. The operator's control panel, electrical outlet bus-bar compartment, and external fuel line entrance is located

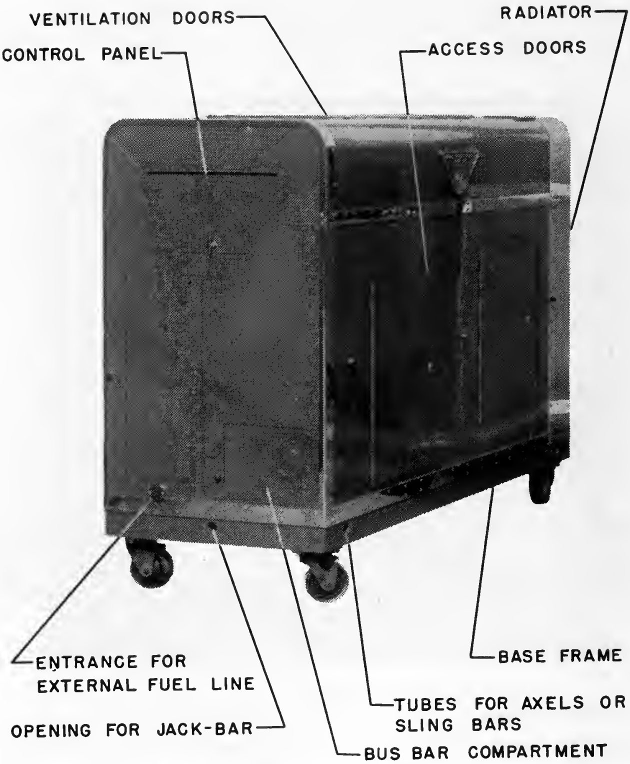


Fig. 5. Mole-700 Power Plant, closed for transport.

on one end-section of the enclosure. The opposite end of the enclosure is formed by the radiator. With the top and sides removed (Fig. 6) the working parts are exposed, yet the plant may be operated for test.

The heat is removed from the engine cooling water by the combination of a large tube and fin radiator and fan (Fig. 7) at the generator end of the plant. The 30-in. diameter fan is belt driven from a sheave on the generator armature shaft and has six variable-pitch blades which are thermostatically controlled to automatically maintain approximately 180 F cooling water temperature. Hence, no more air is drawn through the radiator than is required for adequate engine cooling, and noise which would result from an excess air speed is prevented. A maximum air flow rate of approximately 7000 cu ft/min is sufficient for full load operation in an ambient temperature of 115 F such as might be encountered on a desert location. After the air is drawn through the radiator it is deflected by a sloping partition through adjustable door openings at the top of the enclosure (Fig. 8).

A fan on the coupling end of the generator armature draws outside air from a screened opening below the radiator through air ducts (Fig. 9) into the commutator end of the generator and exhausts it into the engine compartment, after which it passes out of the enclosure through one of the top ventilating doors.

The control panel (Fig. 10) has all of the necessary instruments, switches, etc. for control of both the engine and elec-

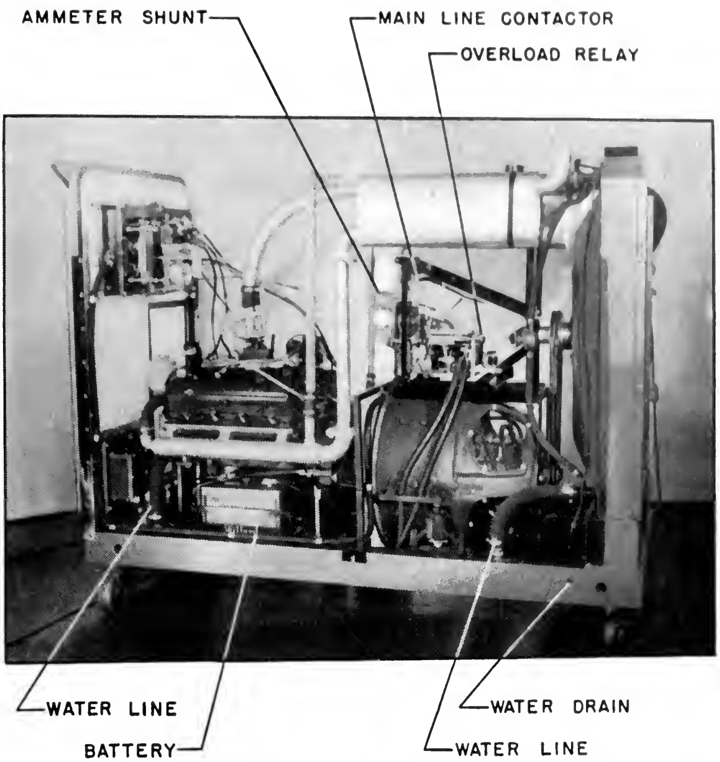


Fig. 6. Left side, with top and sides removed.

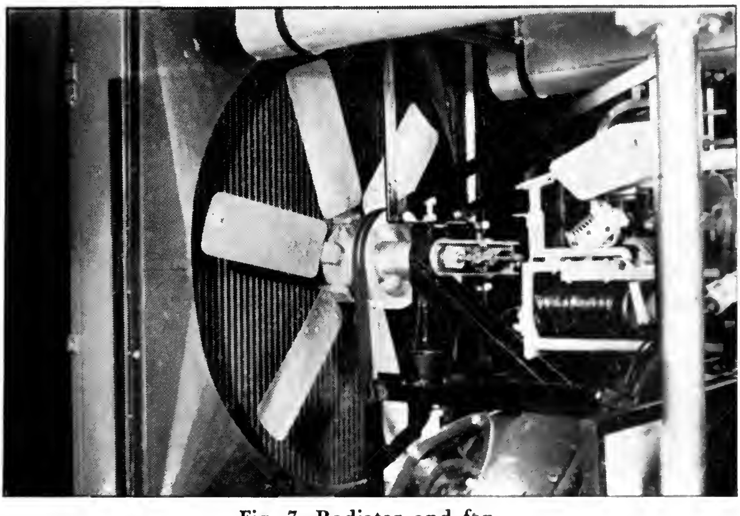


Fig. 7. Radiator and fan.

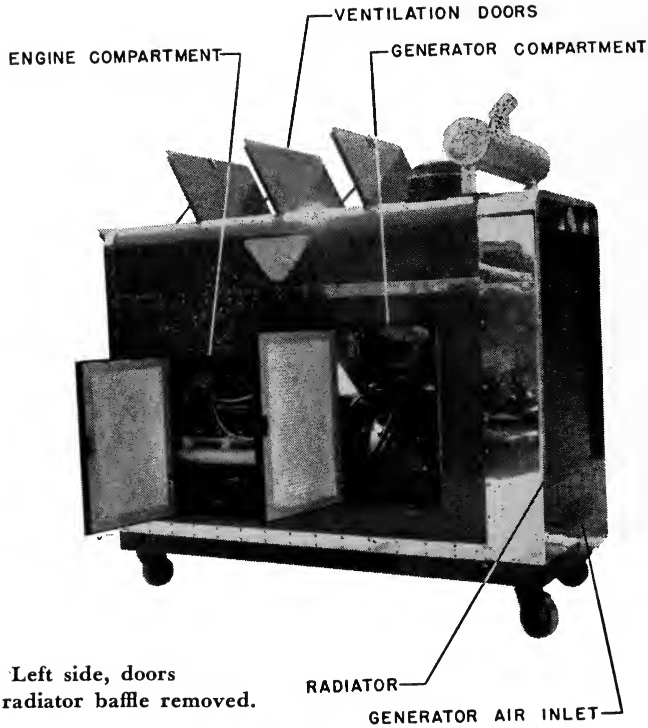


Fig. 8. Left side, doors open, radiator baffle removed.

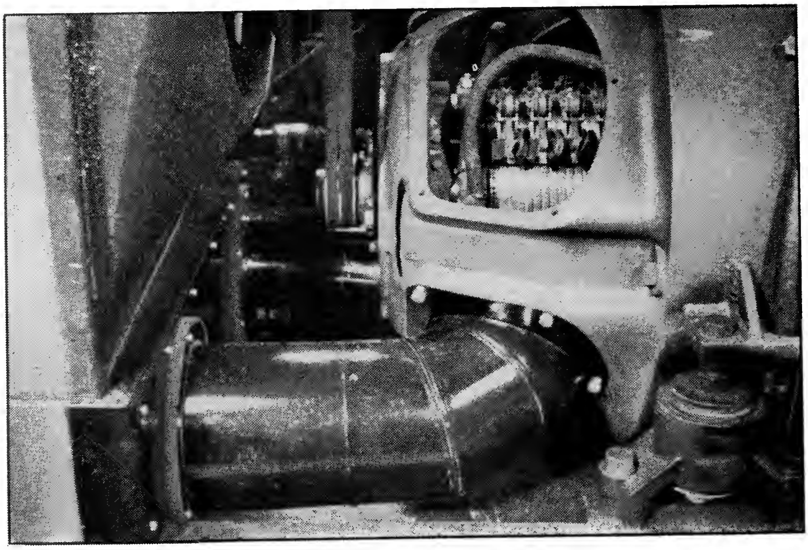


Fig. 9. Air ducts to generator.

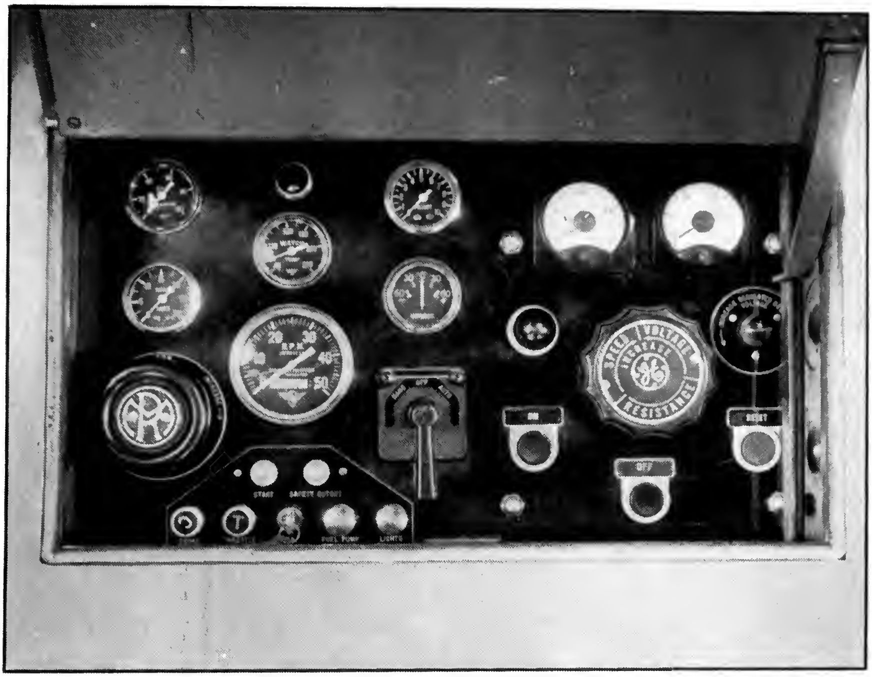


Fig. 10. Control panel.

trical power circuits. The engine controls are located on the left side of the panel and those applicable to the generator are on the right. Engine governed speed may be adjusted by setting the governor control knob. The generator voltage may be controlled either manually with a rheostat, or automatically by a voltage regulator, and the selection between the two is accomplished by positioning the field control selector switch. OFF and ON pushbuttons operate the main line contactor which controls the power-supply voltage at the bus-bar compartment.

Several safety features are provided to prevent damage to the plant. An oil-pressure switch interrupts the ignition circuit should loss of oil pressure occur, and a water temperature switch causes a warning light to glow on the control panel if the engine overheats. A centrifugal overspeed governor interrupts the ignition circuit in the event of excess speed. An overload relay causes the main line contactor to open the electrical power circuit in the event of a short-circuit in the external distribution system. Also, to protect against a failure in the thermostatic control of the pitch of the radiator fan blades, a mechanical means is provided to lock the blades in full pitch.

Silencing of an engine generator set for motion-picture and television location work entails a compromise between the degree of noise reduction and portability. Previous experience gained with the sound insulation design of similar equipment leads to a solution which satisfies both requirements particularly well. The wall construction consists of an outer 20-gauge sheet steel skin with Minnesota Mining undercoating applied on its inner surface. A fibrous asbestos material is sprayed over the undercoating

Fig. 11. Mole-700 Power Plant, prepared for air transport.

to form an additional sound absorbing layer about $\frac{3}{4}$ in. thick, and is protected by two coats of casein base paint and metal hardware cloth. The bottom of the plant is closed with covers consisting of $\frac{1}{2}$ in. thick Celotex between 18-gauge steel sheets. An acoustical partition (Fig. 1) within the housing made of $\frac{1}{2}$ in. thick Celotex faced on both sides by $\frac{1}{8}$ in. thick Transite prevents engine mechanical noise from escaping through the radiatior. All access doors are gasketed. A blanketed baffle spaced a short distance in front of the radiator reduces the air and fan noise and serves as a guard against radiator damage during handling and transportation.

The engine exhaust is muffled by a series-parallel system of silencers (Fig. 1). One 3-pass muffler is connected to the exhaust of each 4-cylinder bank with their outputs joined at the input of a third muffler.

Provisions are made for a variety of types of handling and transporting the equipment (Fig. 5). Casters permit the plant to be conveniently positioned, and steel tubes pass laterally through each end of the base frame for wheel axles or sling bars. Tubular openings at the ends of the base are provided for jacks. The main base frame forms a permanent skid which may be used with rollers with casters removed, and its construction is suitable for assembly of trailer wheels, axles, springs, etc.

The resulting Mole-700 Power Plant 36 in. wide × 82 in. long × 62 in. high, weighing 4,200 lb and capable of generating 650 amp at 120 v, d-c, has a capacity heretofore unequaled with respect to size and weight. Two units are electrically equivalent to one Mole-1400 Power Plant, yet their combined weight is 3,260 lb, or 28%, lighter.

With the operator's panel, bus-bar

compartment, and connection point for fuel line at one end, the radiator at the opposite end, and the ventilation doors, engine exhaust, and carburetor air-cleaner on top, both sides of the enclosure are free of operating components. It is thereby possible for a multiplicity of plants to be positioned side by side and conveniently controlled by one operator.

The dimensions and weight of the overall unit are such that it may be readily transported by air. For example, an emergency situation was recently alleviated by flying one of the Mole-700 Power Plants overnight from Hollywood to Detroit (Fig. 11). The additional expense of air transportation is often negligible as compared to the resulting savings realized by minimizing loss of production time.

The equipment has already demonstrated its usefulness, having satisfactorily performed on numerous locations throughout the United States, Canada and Hawaii over the past several months. The application of new engineering ideas directed toward minimum size and weight has resulted in a new, useful and dependable power package more compact and flexible than any of the previous types of similar equipment.

References

1. "Report of Studio-Lighting Committee," *Jour. SMPE, 51:* 431–436, Oct. 1948.
2. M. A. Hankins and Peter Mole, "Designing engine-generator equipment for motion picture locations," *Jour. SMPTE 55:* 197–212, Aug. 1950.

Glow Lamps for High-Speed Camera Timing

By H. M. FERREE

Some of the unique characteristics of glow lamps are discussed in relation to their use in high-speed photography. Physical and electrical characteristics are given.

THERE ARE, in general use, today, two types of lamps: filament lamps and electric-discharge lamps. Glow lamps belong to the discharge family and share the characteristics peculiar to this group.

For many years, glow lamps have been used as pilot lamps and indicators on various electrical devices. They have to some extent been used in photographic applications. Most recently, their usefulness has extended into the field of electronics, as circuit elements. It is felt that familiarity with some of their unique characteristics will aid in their application to high-speed photography and its related apparatus.

Runaway Characteristic

As in all electric-discharge lamps, at the instant the glow is initiated, the voltage between the electrodes drops while the current is increasing.

Without some ballasting, the current would immediately rise to a destructive value. Therefore some ballast must be provided. However, since the currents involved are very small, a small, inexpensive carbon resistor can be used.

Figure 1 shows a typical group of glow lamps. These range, in wattage, from 1/25 w to 3 w. For best all-around performance, the current density must be held to a rather critical value. As the current is increased the electrode area also must be increased. Increasing the wattage much beyond 3 w would result in electrodes of absurd size.

Some of these lamps are equipped with screw bases, some with bayonet bases and one with wire terminals only. All lamps having screw bases have the necessary ballast resistor built in. This is a safety measure. Screw-base lamps may be put into sockets supplied with 115 v. If there were no resistor in the base, violent failure would result.

Those having bayonet bases or wire terminals do not have integral ballast and a resistor of the proper value must be used in series with the lamp. Table I shows the value of resistor required to operate each lamp at its rated current.

In some applications there may be sufficient resistance or impedance in the circuit to accomplish the necessary ballasting.

Presented on October 6, 1953, at the Society's Convention at New York, by H. M. Ferree, Lamp Div., General Electric Co., Nela Park, Cleveland 12, Ohio.
(This paper was received Sept. 30, 1953.)

Starting and Maintaining Voltage

Glow lamps have a critical starting voltage. At voltages below this starting voltage, the lamp may be considered an open circuit, passing no current.

When the applied voltage is raised to the critical value the lamp starts, current flows and light is emitted.

After starting, the voltage across the electrodes drops to a lower value — the "maintaining voltage" at which it continues to operate. The maintaining voltage is of the order of 15 v below the starting voltage on d-c, while on a-c the difference is less than 5 v.

The electrode surfaces of glow lamps are, to some degree, photoelectric; they emit electrons under the influence of ambient illuminations. Therefore if the lamp is operated in total darkness, the voltage required for starting may be 20 to 50 v higher than normal.

When lamps are totally enclosed, as in the case of cameras, the starting problem is usually taken care of by simply applying the additional potential.

Since the starting voltage increases with age, when used in total darkness, some of the older lamps may fail to start. As insurance, voltages of the order of 150 should be applied.

When lamps such as the NE-51 which have no resistance in the base are used, an adjustable series resistor may be employed to regulate the lamp current. This provides more uniform exposures throughout the life of the lamp and will extend the useful lamp life.

Equivalent Circuit

When conducting, the glow lamp may be considered as a counter emf (electromotive force) in series with a resistance and in parallel with a low order of capacitance.

For purposes of calculations the counter emf may be considered the same as the maintaining voltage. Using values given in Table II, the lamp current, or the external resistance required for a given value of current, other than normal may be calculated by means of the following equation:

$$\text{Lamp current} = \frac{\text{Line volts} - \text{maintaining volts}}{\text{Internal resistance} + \text{external resistance}}$$

As indicated later this lamp current may be used to determine changes in light output as well as the order of increase or decrease in the useful life of the lamp.

Light Output

Glow lamps are relatively low efficiency lamps, averaging about 0.3 lm/w. They are, therefore, not generally considered as illuminating devices. In spite of this, since the characteristic orange-red color contrasts well with surrounding illumination, they have proven quite adequate for many indicator applications. They provide small, relatively cheap and very rugged light sources for indication, identification and under some conditions, a means of illuminating dials of instruments.

The light output of these lamps is

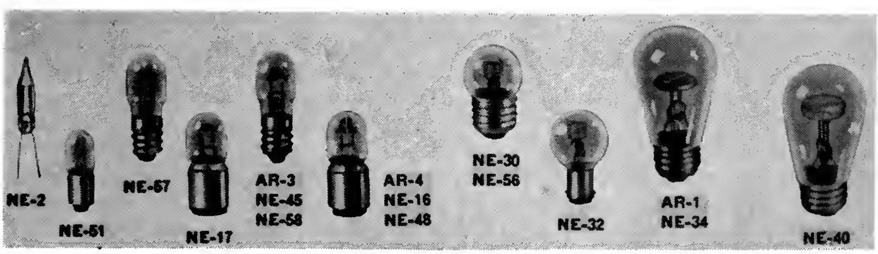


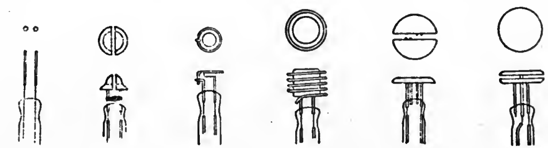
Fig. 1. A typical group of glow lamps.

Table I. Values of Resistor Required to Operate Each Lamp at Its Rated Current.

	Neon													Argon		
Watts, nominal	$\frac{1}{25}$	$\frac{1}{25}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	1	1	1	2	3	$\frac{1}{4}$	$\frac{1}{4}$	2
Volts, circuit	105–125	105–125	105–125	105–125		105–125	105–125	210–250	105–125	105–125	210–250	105–125	105–125	105–125	105–125	105–125
Nominal current, amp	0.0003	0.0003	0.002	0.002		0.002	0.002	0.002	0.012	0.012	0.005	0.018	0.030	0.030	0.0035	0.018
Bulb, clear	T-2	T-$3\frac{1}{4}$	T-$4\frac{1}{2}$	T-$4\frac{1}{2}$	T-$4\frac{1}{2}$	T-$4\frac{1}{2}$	T-$4\frac{1}{2}$	T-$4\frac{1}{2}$	G-10	G-10	G-10	S-14	S-14	T-$4\frac{1}{2}$	T-$4\frac{1}{2}$	S-14
Base	Unbased (wire term.)	S.C. bay. min.	Cand. screw	D.C. bay. cand.	D.C. bay. cand.	Cand. screw	D.C. bay cand.	Cand. screw	Medium screw	D.C. bay. cand.	Medium screw	Medium screw	Medium screw	D.C. bay. cand.	Cand. screw	Medium screw
Max. overall length, in.	$1\frac{1}{16}$	$1\frac{3}{16}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$2\frac{1}{16}$	$2\frac{1}{16}$	$2\frac{1}{16}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$3\frac{1}{2}$
Electrode shape	W-11	W-11	P-3	P-3	P-3	PW-27	PW-27	PW-3	PW-5	PW-5	PW-5	P-2	P-4	P-3	P-3	P-2
Approx. starting voltage: a-c	65	65	65	65		55	55	65	60	60	60	60	60	80	80	65
Approx. starting voltage: d-c	90	90	90	90		75	75	90	85	85	85	85	85	115	115	90
Series resistance, ohms	200,000 ext.	200,000 ext.	300,000 int.	300,000 ext.		300,000 int.	300,000 ext.	100,000 int.	7500 int.	7500 ext.	33,000 int.	3500 int.	2200 int.	15,000 ext.	15,000 ext.	3500 int.
Average useful life, hr	over 25,000	over 12,000	over 7500	over 7500		5000	5000	over 7500	5000	5000	5000	8000	1000	1000	1000	3000
Lamp No.	NE-2	NE-51	NE-45	NE-48	NE-16	NE-57	NE-17	NE-58	NE-30	NE-32	NE-56	NE-34	NE-40	AR-4	AR-3	AR-1

Notes: Bulb designations—Letter indicates shape: T–tubular, G–globular or round, S–pear-shaped. Figures indicate maximum diameter in eighths of an inch.

Electrode shapes:



W-11 P-3 PW-27 PW-5 P-2 P-4

Table II. Values for Calculating Lamp Current

Lamp type	Supply volts	Starting volts	Minimum maintaining volts	Ohms Internal resistance	Ohms External resistance
S-14 3-w neon	120 a-c	53	50	310	2,200
	120 d-c	78	58	220	2,200
S-14 2-w argon	120 a-c	65	62	900	3,500
	120 d-c	90	75	730	3,500
S-14 2-w neon	120 a-c	52	49	420	3,500
	120 d-c	74	60	380	3,500
G-10 1-w neon	120 a-c	45	44	450	7,500
	120 d-c	65	57	400	7,500
T-4$\frac{1}{2}$, $\frac{1}{4}$-w neon	120 a-c	57	56	2600	30,000
	120 d-c	83	64	2200	30,000
T-4$\frac{1}{2}$, $\frac{1}{4}$-w argon	120 a-c	71	70	5500	15,000
	120 d-c	100	80	4200	15,000
T-3$\frac{1}{4}$, $\frac{1}{25}$-w neon	120 a-c	54	42	7500	200,000
	120 d-c	73	55	6000	200,000
T-2 $\frac{1}{25}$-w neon	120 a-c	54	42	7500	200,000
	120 d-c	73	55	6000	200,000

directly proportional to the current. It may therefore be increased or decreased by proper selection of the external resistance. For this reason, some of these lamps, as indicated above, do not have a built-in ballast resistor.

Useful Life

Since glow lamps have no filament, they do not burn out. As lamps, they reach the discard point by a gradual blackening of the bulb and a rise in operating voltage, both of which tend to reduce the light output. Illumination requirements will determine this point.

As circuit elements, where relatively constant voltage devices are usually required, their useful life is determined by the number of hours they may be operated before some definite change in their operating voltage takes place.

The useful life of a glow lamp is inversely proportional to, approximately, the cube of the current. Therefore, for example, doubling the lamp current will reduce the life to approximately one-eighth of normal.

The operating current of these lamps may be increased up to ten times, with a proportional increase in light output, before their electrical characteristics are seriously affected.

As indicated, by the foregoing equation, glow lamps may be operated on voltages higher than design by increasing the value of the series resistor.

Spectral Characteristics

For indicator purposes neon has been found to be the most satisfactory for filling gas. However, for some photographic purposes, lamps filled with argon are available.

Figure 2 shows the spectral characteristics of both the neon and argon lamps, showing that the radiation from neon lamps is confined to the orange-red region of the spectrum while argon radiates principally in the blue-violet and near ultraviolet regions.

High-Speed Cameras

In high-speed cameras, for purposes of analysis and identification, timing marks are usually imprinted on the film. Due to the extremely short exposure time allowable, the lamp radiation must be highly actinic and the lamp must also be capable of rapid response to the timing pulse applied to it.

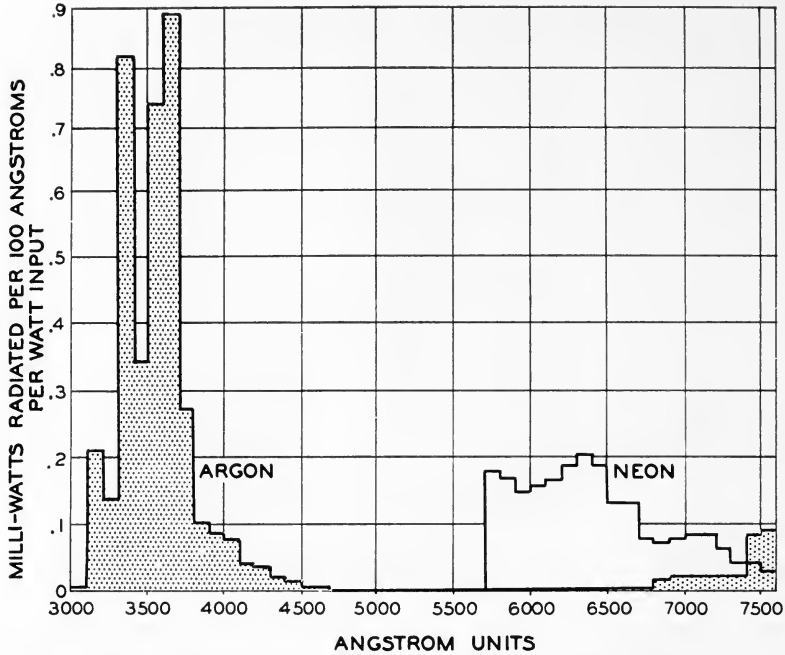


Fig. 2. Spectral characteristics of argon and neon lamps.

When black-and-white film is being used, the argon lamp has been found to meet these requirements very well.

In addition to the AR-1, AR-3 and AR-4 argon lamps shown in Fig. 1, argon lamps of the same physical dimensions as the NE-2 and NE-51 neon lamps are now available. These offer small size units which may be used when space is a consideration.

Argon lamps of the AR-4 type are used in some of the recording units employed in making radio surveys for program rating purposes. Here the lamp imprints a continuous line on the moving film, which by its position and length indicates the station tuned in and the length of time it is tuned in.

The 2-w, AR-1, argon-filled lamp is now being used in contact printers. Low wattage and small size make possible the use of a multiplicity of lamps to produce uniformly luminous areas of any size. Since there are many separate lamps they may be switched to facilitate "dodging."

The increasing use of color film in high-speed photography has brought with it the problem of producing satisfactory timing marks. The ideal light source for this purpose would be one producing white light, which would penetrate all three layers of the film. Today we do not have a gas or gas mixture which will provide a commercially practical, white glow lamp.

In the past, discharge lamps were made, containing CO_2, which did produce essentially white light. These, however, required a means of constantly replenishing the gas.

Glow lamps containing phosphors have been made; however most of the known phosphors are too slow in their response, for this application. Others which are faster present other obstacles when used in glow lamps.

Several years ago, the SMPTE High-Speed Photography Committee brought this problem to us. A neon glow lamp, operating at about five times normal loading was made available. This is the NE-66, now well known.

The timing marks produced by this lamp must be observed by reflected light. These, however, are quite easily seen and practically as satisfactory as a mark seen through the film.

Speed of Response

The rapidity with which a glow lamp may be pulsed is determined by the time required for ionization and deionization of the gas. Accurate data of this type, are not, at present, available on all types of glow lamps. However it is known that ionizing time is a function of the applied voltage, in excess of that required for starting.

In lamps of the sizes usually employed in high-speed cameras, the application of voltages 5 to 10 v in excess of starting will result in ionizing times of the order of 200 to 250 μsec, while increasing this to 50-v excess will reduce the time to, perhaps, 5 to 10 μsec. Complete deionization may require as high as 30 msec.

Other Applications

Some of the unique characteristics of glow lamps adapt them to applications where their light output is not necessarily essential.

Glow lamps provide small, low-current circuit elements for use in many electronic devices such as amplifiers, oscillators and control units which might be used in connection with high-speed cameras, television equipment or related applications.

Their use in these fields may be broken down into three basic circuits.

Figure 3A shows the basic circuit for voltage-controlled devices. Here the lamp is connected across the dividing network so that when a predetermined voltage appears across the network, a voltage equal to the starting voltage appears across the lamp. Immediately the lamp starts, current flows and light is emitted. Control of associated equipment may therefore be accomplished by the use of sensitive relays in the lamp circuit or photoelectrically.

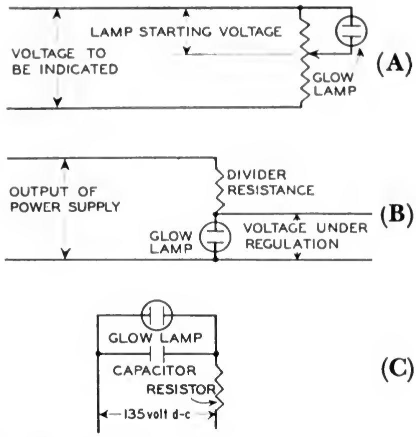


Fig. 3. Glow lamp (A) in basic circuit for voltage-controlled devices; (B) as gas diode voltage regulator; (C) as an oscillator.

Since glow lamps are, relatively, constant voltage devices, they may be used as gas diode voltage regulators in circuit (Fig. 3B) whose currents do not exceed the maximum lamp rating (Fig. 3B).

One of the most interesting uses for a glow lamp is as an oscillator (Fig. 3C). When connected in the familiar RC circuit shown in Fig. 3C, the lamp can be made to pulse or operate at frequencies ranging from one pulse in several seconds to frequencies well into the audio range.

For the very low frequency range it may be found better to connect the capacitor across the resistor, rather than across the lamp.

A glow lamp may be pulsed or caused to lock into a master oscillator by the use of a third electrode to which the input may be connected. This electrode may take the form of a conductive coating placed on the bulb or an external grid placed around the outside of the bulb.

Glow lamps are versatile devices. They are rugged, low in cost and require little current. It is felt that their unique features make them worthy of consideration in many applications, which fall within the scope of this organization.

References

A. M. Erickson, "Photographic instrumentation of timing systems," *Jour. SMPTE, 61:* 165–174, Aug. 1953.

H. M. Ferree, "Some characteristics and applications of negative glow lamps," *Elec. Eng., 60:* 8–11, Jan. 1941.

W. R. Kincheloe, Jr., "Neon lamps as circuit elements," Report No. 10, Electronics Research Laboratory, Stanford University, Palo Alto, Calif.

Bibliography on High-Speed Photography

Including Schlieren and Cathode-Ray Oscilloscope Photography

Like its predecessor, which was published in the January 1951 *Journal* and *High-Speed Photography*, Vol. 3, this bibliography has been arranged in the following categories: General, Cameras, Lighting, Oscillography, Schlieren, Technical and Techniques, X-Ray.

The task of compiling the items was again undertaken by Miss Elsie Garvin, Librarian, Research Library, Eastman Kodak Co., Rochester, N.Y., and the bibliography was classified by John H. Waddell. It will be reprinted early in 1954 in Vol. 5 of *High-Speed Photography*.

I. GENERAL

High Speed Photography, H. F. Quinn, *Eng. J., 32:* 544–549, Sept. 9, 1949.

The Motion-Picture Camera in Science and Industry, H. M. Lester, *Am. Ann. Phot., 64:* 74–80, 1950.

La Cinématographie à Haute Frequence, M. Deribéré, *Électricité, 34:* 165–168, June 1950.

La Photographie Ultra-Rapide dans l'Industrie, M. Deribéré, *Électricité, 34:* 225–228, Sept. 1950.

Appareil de Grand Rendement pour la Chronophotographie des Éclairs, D. J. Malan, *Rev. d'Optique, 29:* 513–523, Oct. 1950.

Die Entwicklung der Momentphotographie und der elektrisch gesteuerte Kameraverschluss, H. Windischbauer, *Phot. Korr., 85:* 100–102, 104, #11/12, 1950.

High-Speed Cinematography, R. H. Cricks, *Functional Phot., 2:* 11–13, 24, May 1951.

High Speed Photography, E. L. Perrine, *The Frontier, 14:* 15–17, 20, June 1951.

Grundlagen für die messtechnische Anwendung der Kinematographie, insbesondere zur Untersuchung schnellverlaufender Vorg¨nge, H. Schardin, *Schweizerische Photo-Rund.:* 294–303, #14, July 30, 1951. (*A lecture given at the 1950 Zurich conference on high-speed photography.*)

You Can't Argue With the Camera, W. A. Vogler, *Am. Cinemat., 32:* 308, 328–329, Aug. 1951.

High-Speed Photography Applied to Production Quality, J. H. Waddell, *Tooling and Production, 17:* 76, 80, 84, 202, 210, 214, Oct. 1951.

Progress in Photographic Instrumentation in 1950, K. Shaftan, *Jour. SMPTE, 57:* 443–488, Nov. 1951. (Bibliography.)

Scanning the Field for Ideas: High-Speed Photography, *Machine Design, 23:* 102, Nov. 1951.

Electronic Flash Photography, R. L. Aspden, *Aircraft Eng., 23:* 354–360, Dec. 1951.

Cathode-Ray Tube for Recording High-Speed Transients, S. T. Smith, R. V. Talbot and C. H. Smith, Jr., *Proc. I.R.E., 40:* 297–302, Mar. 1952.

Progress in Photography, 1940–50. D. A. Spender, Editor-in-Chief, Focal Press, London and New York, 1951. Includes "Flash Photography" by G. A. Jones, pp. 191–199; "Photography of Motion" by J. H. Waddell, pp. 200–211; "Schlieren Photography" by J. M. Waldram.

The Photographic Study of Rapid Events, W. D. Chesterman, Clarendon Press, Oxford, 1951.

Combustion, Flames and Explosion of Gases, L. Barnard and G. von Elbe, Academic Press, N.Y., 1951. (*Chapter VI, pp. 211–220 deals with flame photography and numerous examples of Schlieren photography appear throughout the book.*)

Einführung in die wissenschaftliche Kinematographie, W. Faasch, W. Knapp, Halle, 1951.

Grundlagen der Funkenkinematographie, I and II, H. Schardin and E. Fünfer, *Z. angew. Physik, 4:* 185–199, #5; 224–238, #6, 1952.

High-Speed Cinematography, J. H. Waddell, *Am. Cinemat., 33:* 354–356, Aug. 1952.

High-Speed Photography in Science and Industry, M. Beard, *PSA Jour., 8:* 476–477, 488, Aug. 1952.

High-Speed Photography, C. D. Miller and K. Shaftan, *Product Eng., 23:* 167–182, Sept. 1952.

La Mesure des Courtes Durées, P. Fayolle, *Actes Coll. inter. Mecan. II. Publ. sci. tech. Min. Air, Paris #250:* 51–64, 1951.

High-Speed Photography, K. Morgan, *Interchemical Rev., 11:* 59–70, #3, Autumn 1952.

Chronophotography of a Reproducible Phenomenon, R. B. Edmonson, E. L. Gayhart and H. L. Olsen, *Phot. Eng., 3:* 135–144, #3, 1952.

Origins of Photographic Instrumentation, F. Smith, *Phot. Eng., 3:* 145–160, #3, 1952. (*This contains brief historical sketches of some kinds of high-speed work.*)

History and Present Position of High-Speed Photography in Great Britain, W. D. Chesterman, *Jour. SMPTE, 60:* 240–246, Mar. 1953.

High-Speed Photography, K. Morgan, *Industrial Phot., 2:* 39–40, 42, Apr. 1953.

High Speed Photography by Means of the Image Converter, J. A. Jenkins and R. A. Chippendale, *Philips Tech. Rev., 14:* 213–225, Feb. 1953.

II. CAMERAS

Report on the Development of a Method for 50,000 Exposures/Sec of Standard Size Film under Direct Lighting, K. Altner and D. Kreidel, P. B. Report 105,-736, 1946.

An Electro-Optical Shutter for Photography, A. M. Zarem, F. R. Marshall and F. L. Pode, *Elect. Eng., 68:* 282–288, Apr. 1949.

New High-Speed Camera Probes Mystery of Human Eye for Science, *Bus. Screen Mag., 11:* 36, May 1950.

A Multiple Kerr-Cell Camera, A. M. Zarem and F. R. Marshall, *Rev. Sci. Instr., 21:* 514–519, June 1950.

The Operation and Photographic Characteristics of Kerr-Cell Type of Electro-Optical Shutter, A. E. J. Holtham and H. A. Prime, *Proc. Phys. Soc., 63B:* 561–572, Aug. 1, 1950.

Low-Cost, 16-mm Camera for Rocket Photography, R. E. Mueser and T. F. Irvine, Jr., *J. Am. Rocket Soc.:* 119–125, #82, Sept. 1950.

A Kerr Cell Camera and Flash Illumination Unit for Ballistic Photography, H. F. Quinn, W. B. McKay and O. J. Bourque, *J. Appl. Phys., 21:* 995–1001, Oct. 1950.

High-Speed Intermittent Camera, R. R. Shaw, *Am. Documentation, 1:* 194–196, Oct. 1950. (*Developed for use in the Rapid Selector.*)

Camera Design Based on Slit Principle, *Machine Design, 22:* 120–121, Nov. 1950. (*Beckman and Whitley slit camera.*)

A Discussion on Detonation: A New Photographic Method for Studying Fast Transient Phenomena, J. S. Courtney-Pratt, *Proc. Roy. Soc., 204A:* 27–29, Nov. 22, 1950. (*Cathode-ray type.*)

A Discussion on Detonation: Two New Streak Cameras, C. A. Adams, *Proc. Roy. Soc., 204A:* 19–20, Nov. 22, 1950.

An Iconoscope Electro-Optical Shutter for High-Speed Photography, H. A. Prime and R. C. Turnock, *Proc. I.E.E., 97:* Pt. II: 793–796, Dec. 1950.

Use of Image Converter Tube for High-Speed Shutter Action, A. W. Hogan, *Proc. I.R.E., 29:* 268–270, Mar. 1951.

Kerr-Cell Photography of High Speed Phenomena, E. M. Pugh, R. v. Heine-Geldern, S. Foner and E. C. Mutschler, *J. Appl. Phys., 22:* 487–493, Apr. 1951.

A Rapid-Action Shutter with No Moving Parts, H. E. Edgerton and C. W. Wyckoff, *Jour. SMPTE, 56:* 398–406, Apr. 1951.

Three-Dimensional Motion Picture Applications, R. V. Bernier, *Jour. SMPTE, 56:* 599–612, June 1951.

Use of Image Phototube as a High-Speed Camera Shutter, A. W. Hogan, *Jour. SMPTE, 56:* 635–641, June 1951.

A Continuous Motion Camera for Multiple Exposure of 35mm Film, E. L. R. Webb, *Canadian J. Tech., 29:* 401–405, Sept. 1951. (*Recording at 4 in./sec of transient signals by photographing the deflection modulated spot of a cathode-ray tube. Film passes through the camera twenty times, writing one wavy line each trip and thus recording 2000 ft of information on a standard 100-ft roll of film.*)

The Performance of Image Converters as High-Speed Shutters, R. C. Turnock, *Proc. I.E.E., 98, Pt. II:* 635–641, Oct. 1951. (*Use is streak records for spark ultraviolet and infrared spark spectra.*)

A 35-mm High-Speed Cinematograph Camera, W. D. Chesterman, *J. Sci. Instr., 28:* 301–308, Oct. 1951.

The Camera That Outspeeds the Fastest Jet, *Functional Phot., 3:* 6–7, Dec. 1951.

High-Constant-Speed Rotating Mirror, J. W. Beams, E. C. Smith and J. M. Watkins, *Jour. SMPTE, 58:* 159–168, Feb. 1952.

High-Speed Motion Picture Cameras from France, P. M. Gunzbourg, *Jour. SMPTE, 58:* 259–265, Mar. 1952.

A Multiple Exposure Camera (developed by A. P. Boysen and W. D. Goodale, Jr.), *Bell Lab. Record, 30:* 234–235, May 1952. (*Study of how coins behave in chutes of coin collectors. Photographs at intervals of 1.6 msec.*)

Optical Problems in High-Speed Camera Design, J. C. Kudar, *Jour. SMPTE, 58:* 487–490, June 1952.

Some New Image Converter Tubes and Their Applications, J. A. Jenkins and R. A. Chippendale, *Electr. Eng., 24:* 302–307, July 1952. (*Includes circuit diagram of the A.R.E. camera.*)

Electro-Optical Shutters for Ballistic Photography, B. J. Ley and P. Greenstein, *Electronics, 25:* 123–125, Sept. 1952.

The Development of a Multi-Flash Camera and Its Application to the Study of Liquid Jets, N. A. Mahrous, *Brit. J. Appl. Phys., 3:* 329–331, Oct. 1952.

Image Converter Tubes and Their Application to High Speed Photography, J. S. Courtney-Pratt, *Phot. J., 92B:* 137–148, Sept.-Oct. 1952.

Image Converter Techniques Applied to High Speed Photography, R. A. Chippendale, *Phot. J., 92B:* 149–157, Sept.-Oct. 1952.

An Electronically Operated Kerr Cell Shutter, K. D. Froome, *Phot. J., 92B:* 158–161, Sept.-Oct. 1952. (*Used for taking low power photomicrographs of the development of cathode phenomena in arc discharges.*)

Camera records Position vs. Time, *Chem. Eng. News, 30:* 5308, Dec. 15, 1952. (*Beckman and Whitley's Model 168 research camera has an image wiped onto the film at a sweep rate of 5.446 mm/μsec by a mirror rotating at 50,000 rpm.*)

A High-Speed Rotating-Mirror Frame Camera, B. Brixner, *Jour. SMPTE, 59:* 503–511, Dec. 1952.

Rapid Camera Shutter, *Mech. Eng., 74:* 323, Apr. 1952. (*A new camera shutter, the Rapidyne, which is claimed to be two to three times faster than any mechanical interlens camera shutter today, size for size, has been developed at Fairchild Camera and Instrument Corp., Jamaica, N.Y.*)

Die Mehrfach-Funken-Kamera und ihre Anwendung in der technischen Physik, H. Schardin, *Z. angew. Physik, 5:* 19–24, Jan. 1953.

Fast Multiple Frame Photography, J. S. Courtney-Pratt, *J. Phot. Sci., 1:* 21–39, Jan.-Feb. 1953. (*A new method. The record is a composite plate which yields a sequence of independent two-dimensional pictures. A lenticular plate is used to dissect the image into elements that are moved over the photographic emulsions by altering the direction in which light falls on the plate. In the simplest camera scanning is performed by the rotation of a Nipkov disk between the components of the camera lens. 200 pictures can be recorded at rates up to 50,000 per second. A change of Nipkov disk allows color photography on ordinary "black and white plates."*)

A Camera for Study of Rapid Self-luminous Events, J. Chambers, *Phot. Eng. 4:* 22–24, #1, 1953.

Simple Electronic Devices for High-Speed Photography and Cinematography, P. Fayolle and P. Naslin, *Jour. SMPTE, 60:* 603–626, May 1953.

Design and Construction of High-Speed Camera and Its Application to Certain Combustion Problems, A. H. Howland and M. J. G. Wilson, *Fuel, 31:* 274–287, July 1952.

III. LIGHTING

New Lighting for High-Speed Photography, W. R. Plant, *Gen. Elec. Rev.*, *52:* 22–27, June 1949.

A Compact-Source Lamp for High-Speed, E. J. G. Beeson, *Elec. Times*, *117:* 447–450, Mar. 23, 1950.

The Cine Flash: A New Lighting Equipment for High-Speed Cinephotography and Studio Effects, H. K. Bourne and E. J. G. Beeson, *Jour. SMPTE*, *55:* 299–312, Sept. 1950.

A Study of the Short Duration, High Intensity Electric Arc as a Source of Visible Light, G. D. Hoyt and W. W. McCormick, *J. Opt. Soc. Am.*, *40:* 658–663, Oct. 1950.

Electronic Flash (Camerette #97) The How and Why of Electronic Flash, M. Mooney, *Camera Mag.*, *73:* 83–113, Nov. 1950.

Electronic Flash (Camerette #97) Present Day Speedlights, R. Connolly, *Camera Mag.*, *73:* 113–118, Nov. 1950. (*A Catalog of speedlights.*)

High Intensity Short Duration Spark Light Source, J. A. Fitzpatrick, J. C. Hubbard and W. J. Thaler, *J. Appl. Phys.*, *21:* 1269–1271, Dec. 1950.

A New Flash Illumination Unit for Ballistic Photography, H. F. Quinn and O. J. Bourque, *Rev. Sci. Inst.*, *22:* 101–105, Feb. 1951.

Visual Observation Equipment, C. A. H. Pollitt, *Electr. Eng.*, *23:* 177–178, May 1951. (*Description of Stroboflood units for high level lighting.*)

Use of "Exploding Wires" as Light Sources of Very High Intensity and Short Duration, W. M. Conn, *J. Opt. Soc. Am.*, *41:* 445–449, July 1951.

High-Power Photo-FlashTubes, M. Laporte, *Nature*, *168:* 552, Sept. 29, 1951.

Light Source for Small-Area High-Speed Motion Picture Photography, R. L. Derby and A. B. Webb, *Jour. SMPTE*, *57:* 247–248, Sept. 1951.

A New Power Stroboscope for High-Speed Flash Photography, W. D. Chesterman, D. R. Glegg, G. T. Peck and A. J. Meadowcroft, *Proc. I.E.E.*, *98, Pt. II:* 619–634, Oct. 1951. (*Applications to cavitation research.*)

The Electrical and Luminous Characteristics of Short Air Sparks Suitable for High-Speed Photography, W. G. Standring and J. S. T. Looms, *Proc. Phys. Soc.*, *65B:* 108–115, Feb. 1952.

Problems of Underwater Illumination, W. D. Chesterman and J. B. Collins, *Trans. Illum. Eng. Soc.* (*London*), *17:* 193–225, #8, 1952. (*Cavitation research.*)

Explosive Argon Flashlamp, C. H. Winning and H. E. Edgerton, *Jour. SMPTE*, *59:* 178–183, Sept. 1952.

Lighting for High-speed Motion Pictures, J. H. Waddell, *Am. Cinemat.*, *33:* 389, 404–405, 408, Sept. 1952.

Flash Cinematography, R. H. J. Brown, *Phot. J.*, *92B:* 129–133, Sept.-Oct. 1952. (*Equipment was developed for research on animal locomotion.*)

A Synchronized Flash-Discharge System for High-Speed 35mm Cinematography, W. D. Chesterman and G. T. Peck, *Phot. J.*, *92B:* 133–135, Sept.-Oct. 1952. (*Power stroboscope taking pictures allowing high-speed flash rates up to 4,000 per sec.*)

Double-Flash Microsecond Silhouette Photography, H. E. Edgerton, *Rev. Sci. Instr.*, *23:* 532–533, Oct. 1952. (*Exposure time $^1/_8$ μsec. An 8-in. square Ektalite Fresnel lens is used to focus light from the spark into the camera lens.*)

An Introduction to Spark Shadowgraph Techniques, R. Prescott, *Phot. Eng.*, *3:* 121–128, #3, 1952.

Repetitive Working of Photoflash Tubes, A. S. V. McKenzie, *Electr. Eng. 25:* 122–123, Mar. 1953.

IV. OSCILLOGRAPHY

Messung schnellveränderlicher mechanischer Grössen mittels Quarzgeber, Photozellengeber und Elektronenstrahl-Oszillograph, M. Nier, *Trans. Instruments and Measurements Conference, Stockholm, 1949:* 150–153, 1950.

New Equipment for Single-Frame Photo-Recording, *The Oscillographer*, *12:* 3–16 July-Sept. 1950. (*Details on the Du Mont, Type 295 camera.*)

A Cathode-Ray Rapid-Record Oscillograph, F. H. Hibbard, *Bell Lab. Record*, *28:* 438–441, Oct. 1950. (*This is designed* *as a cupboard arrangement, with automatic development arrangement of the paper strips.*

Cathode-Ray Oscilloscope Photography, W. J. Schubert, *PSA Jour.*, *17:* 247–254, May 1951.

Cathode Ray Recorders for Missile Application, C. H. Schlesman, *Phot. Eng.*, *3:* 78–88, #2, 1952.

Polarization Measurements of Low Frequency Echoes, E. L. Kilpatrick, *J. Geophysical Res.*, *57:* 221–226, June 1952. (*Photography of echo on time axis and polar and phase oscillograph records.*)

Photographing High-Speed Cathode-Ray Oscilloscope Traces, H. J. Peake, *PSA Jour.* (*Phot. Sci. Tech.*), *18B:* 126–130, Dec. 1952.

V. SCHLIEREN

A Sharp-Focusing Schlieren System, W. S. Miller, Jr., A. Kantrowitz and R. L. Trimpi, *Phot. Eng.*, *1:* 119–129, Oct. 1950; article appeared with Kantrowitz and Trimpi as authors in *J. Aeronautical Soc. 17:* 311–314, 319, May 1950.

A High-Speed Stereoscopic Schlieren System, J. H. Hett, *Jour. SMPTE*, *56:* 214–218, Feb. 1951. (*A Fastax camera and a polarizing projection system were used, taking 90,000 frames/sec.*)

Photography in Electrophoresis of Hemolyzed Sera, G. Kegeles and F. J. Gutter, *J. Am. Chem. Soc.*, *73:* 3539–3540, July 1951. (*Infrared Schlieren photography.*)

A Repetitive Spark Source for Shadow and Schlieren Photography, G. K. Adams, *J. Sci. Instr.*, *28:* 379–384, Dec. 1951. (*Two methods: the first gives a limited number of discharges (four to eight) at individually determined time intervals of ten microseconds or greater with an error of less than one microsecond and is intended for the production of superimposed photographs on a stationary film; the second, used with a rotating drum or mirror camera, gives light pulses up to 10,000 per sec.*)

A Schlieren Apparatus Giving an Image in Colour, D. W. Holder and R. J. North, *Nature*, *169:* 466, Mar. 15, 1952.

An Improved Shadowgraph, P. Husta, *Bell Lab. Record*, *30:* 223–226, May 1952. (*Shadow oscillographs are made by condensing light from a brilliant source onto the moving parts being studied and projecting the image on the photographic recording paper.*)

Focussing Schlieren Systems, R. W. Fish and K. Parnhan, *Aero. Res. Counc. London. Curr. Pap. 54:* 14 pp., 11 figs., Nov. 1950, publ. 1951.

Radial Symmetry in a Schlieren Image, R. B. Edmonson, E. L. Gayhart and H. L. Olsen, *J. Opt. Soc. Am.*, *42:* 984–985, Dec. 1952.

An Interferometer-Schlieren Instrument for Aerodynamic Investigations, R. E. Blue and J. L. Pollack, *Rev. Sci. Instr.*, *23:* 754–755, Dec. 1952.

The Sensitivity and Range Required in a Toepler Schlieren Apparatus for Photography of High-Speed Air Flow, W. A. Mair, *The Aeronautical Quarterly*, *4F:* 19–50, Aug. 1952.

A High-Speed Schlieren Technique for Investigation of Aerodynamic Transients, W. S. Bradfield and W. Y. Fish, *J. Aeronaut. Sci.*, *19:* 418–420, 432, June 1952. (*Development of the technique for the system. Data at Mach number of 3.5 in intermittent wind tunnel. Illustrated.*)

Schlieren Analysis of Inert Gas Arc Shields, W. B. Moen and G. J. Gibson, *The Welding Journal*, *31:* 208–213, Mar. 1952. (*Comparison study of helium and argon as arc shields with nonconsumable electrode equipment.*)

Längsschwingungen von Flammen in geschlossen langgestreckten Verbrennungsbomben, U. Neubert, *Z. angew. Physik*, *4:* 122–126, Apr. 1952. (*Schlieren cine-photographs (200–500 frames/sec) of flames of propane-air mixtures.*)

VI. TECHNICAL AND TECHNIQUES

Electronic Flash (Gas Discharge) Tube in Photography of the Anterior Segment of the Eye, R. R. Trotter and W. M. Grant, *Arch. Ophthalmol.*, *40:* 493–496, Nov. 1948.

Some Flow Properties of Solutions of Polymers, C. N. Davies, *Proc. Int. Rheological Conference, 1948:* Pt. II, 152–159; discussion Pt. III, 52–54, 1949.

Solving Wind Tunnel Problem, R. McLarren, *Aviation Week*, *50:* 19–20, 22, 24, June 20, 1949.

Preliminary Investigation of Use of After-

glow for Visualizing Low-Density Compressible Flows, T. W. Williams and J. M. Benson, *NACA TN 1900:* June 1949. 23 pp.

Measurement of Progressive Errors in Machine Tools using High-Speed Photography, *Engineering (London) 168:* 679–680, Dec. 23, 1949; *Machinery (London), 75:* 870–873, 875, Dec. 15, 1949.

Photographic Recording of Ultra High-Speed Phenomena, C. H. Johansson, *Trans. Instruments and Measurements Conference, Stockholm, 1949:* 132–135, 1950.

Electronics in Short-Time Measurement and High-Speed Photography and Kinematography, P. Naslin, *Trans. Instruments and Measurements Conference, Stockholm, 1949:* 139–149, 1950.

The Investigation of Eye Movements, M. P. Lord and W. D. Wright, *Reports on Progress in Physics, 13:* 1–23, 1950.

Ueber ein einfaches Verfahren zur kinematographischen Aufnahme schnell verlaufender Vorgänge, H. Bartles and B. Eiselt, *Optik, 6:* 56–58, Jan. 1950.

Single Pulse Recording of Radar Displays; Photographing Technics, L. C. Mansur, *Tele-Tech, 9:* 30–33, Jan. 1950.

Ergebnisse der kinematographischen Untersuchung des Glasbruchvorganges, H. Schardin, *Glastechnische Ber., 23:* 1–10, Jan.; 67–79, Mar.; 325–336, Dec. 1950.

High-Speed Photography in Paper Mill Maintenance, J. H. Niemeyer, *Paper Trade J., 131:* 22, July 13, 1950.

The Pressurized Ballistics Range at the Naval Ordnance Laboratory, L. P. Giesler, *Jour. SMPTE, 55:* 53–59, July 1950.

Ultra-Fast Photographs With Electronic Flash Apparatus, S. Magun, *Camera (Luzern), 29:* 212–6, #7, 1950. (*Uses an argon-filled chamber. Exposures of 1/20,000 sec.*)

Photography and the Study of Underwater Missiles, W. H. Christie, *PSA Jour. (Phot. Sci. and Tech.), 16B:* 55–58, Aug. 1950.

Transient Testing of Loudspeakers, M. S. Corrington, *Audio Eng., 34:* 9–13, Aug. 1950.

Photo Checkup for Bowlers, R. L. Eastman, *Pop. Phot., 27:* 109, Aug. 1950.

Kinematographic Recording of the Velocity of Arterial Blood-Flow, J. M. Potter and D. A. McDonald, *Nature, 166:* 596–597, Oct. 7, 1950.

The High-Speed Photography of Underwater Explosions, P. M. Fye, *Jour. SMPTE, 55:* 414–424, Oct. 1950.

Simultaneous Photography of Self-Luminous and Non-Self-Luminous Effects, J. S. Rinehart, *Rev. Sci. Instr., 21:* 939–940, Nov. 1950.

Hypersonic Research Facilities at the Ames Aeronautical Laboratory, V. I. Stevens, *J. Appl. Phys., 21:* 1150–1155, Nov. 1950.

A Photographic Method for Displacement/Time Recording, F. M. Bruce, *Brit. J. Appl. Phys., 1:* 291–293, Nov. 1950.

Study of Deformation at High Strain Rates Using High-Speed Motion Pictures, H. I. Fusfeld and J. C. Feder, *ASTM Bulletin #170:* 75–79, Dec. 1950.

High-Speed Photography of Reflection-Lighted Objects in Transonic Wind Tunnel Testing, E. R. Hinz, C. A. Main and E. P. Muhl, *Jour. SMPTE, 55:* 613–626, Dec. 1950.

High-Speed Motion Pictures Detect Defects in Design, L. G. Waller, *Machine Design, 22:* 143–145, Dec. 1950.

Zweidimensional Farbschlierenverfahren, H. Wolter, *Bild und Ton, 3:* 376–8, Dec. 1950; this method is described in greater detail in *Ann. Physik (6), 8:* 1–10, #1/2, 1950.

Photographs of Sprays from Pressure Jets, A. Simons and C. R. Goffe, *Ministry of Supply Report and Memoranda #2343 (9975) Aeronautical Research Council Technical Report:* London, H.M.S.O. 1950 (Labelled as PB Report 101,255).

The "Photoflux" Series of Flashbulbs, G. D. Rieck and L. H. Verbeek, *Philips Tech. Rev., 12:* 186–192, Jan. 1951. (*Photographs of a burning "Photoflux" flashbulb taken at a speed of 3000 pictures per second.*)

Recording Motion of a Watch Balance Wheel by Watch-Case Reaction, E. C. Lloyd, *Instr., 24:* 154–155, 205–206, Feb. 1951.

Motion Pictures (In section "Keeping up With Photography"), *Am. Cinemat., 32:* 48, Feb. 1951. (*Eastman Hi-speed camera used to take motion pictures of the expansion and contraction of explosion bubbles.*)

15,000 R.P.M., *J. Biol. Phot. Assoc., 19:* 44, Feb. 1951. (*Flash duration of 1/24,000 sec motion picture of a dental drill rotating at 15,000 r.p.m.*)

Photographic Study of Surface-Boiling Heat

Transfer to Water with Forced Convection, F. C. Gunther, *Trans. Am. Soc. Mech. Eng.*, *73:* 115–123, Feb, 1951.

The Application of Photography to Papermill Problems, F. P. Hughes, *Brit. Paper and Board Makers' Assoc. Proc. of Tech. Sect.*, *32:* 77–88, Pt. 1, Feb. 1951.

Source of Light Recorded in Photographs of Detonating Explosives, S. Paterson, *Nature*, *167:* 479–481, Mar. 24, 1951.

Photographic Study of the Polymer Cycle in Injection Molding, G. D. Gilmore and R. S. Spencer, *Modern Plastics*, *28:* 117–118, 120, 122, 124, 180, 183, 185, Apr. 1951.

Bird Photography with the "A.P." Speedlamp, J. Warham, *Amat. Phot.*, *101:* 448–450, May 9, 1951.

A Time-Motion Study by Methods of High-Speed Cinematography, H. W. Baer, B. F. Cohlan and A. R. Gold, *Jour. SMPTE*, *56:* 513–518, May 1951.

Slide Rule for Analyzing High-Speed Motion Picture Data, K. W. Maier, *Jour. SMPTE*, *56:* 623–634, June 1951.

See the Ear Hear—a Macroscopic-Stroboscopic Cinematographic Study of the Ear, H. G. Kobrak, *J. Biol. Phot. Assoc.*, *19:* 99–104, Aug. 1951.

Freezing a Firecracker, *U.S. Camera*, *14:* 76, 108, July 1951. (*H. E. Edgerton and H. E. Grier designed a camera with magneto-optic shutter capable of exposures from 4 to 10 millionths of a second.*)

Analyse Photographique de l'Injection du Polystyrene, G. D. Gilmore and R. S. Spencer, *Ind. Plastiques Modernes*, *3:* 30–33, July-Aug. 1951.

Practical Application of High-Speed Photography in Business Machines, W. L. Hicks and R. L. Wright, *Jour. SMPTE*, *57:* 1–8, July 1951.

Simultaneous High-Speed Arc Photography and Data Recording With a 16-mm Fastax Camera, E. L. Perrine and N. W. Rodelius, *Jour. SMPTE*, *57:* 140–144, Aug. 1951.

Measurement and Recording of Vibration, R. Hammond, *Mech. World*, *130:* 96–98, Aug. 3, 1951.

Colour Photography by Electronic Flash, J. Scales-Manners, *Functional Phot.*, *2:* 19–20, Sept. 1951.

Experiments on the Ultrasonic Unmixing of Liquid Solutions, C. A. Boyd and R. J. Zeniner, *Phys. Rev.*, *83:* 1059–1060, Sept. 1, 1951.

Self-Adjusting Timer for Bullet Photography, J. Burlock, *Rev. Sci. Instr.*, *22:* 743–745, Oct. 1951.

Photographic Recording of an Explosion Wave Formed Outside a Linear Charge, (in Russian), S. B. Ratner, *J. Tech. Phys. USSR*, *20:* 1422–1425, #12, 1951; abst. from *Phys. Abst.* #7337, 1951.

Discrete Photograph of an Ultra-Speed Event With General Radio Camera, W. A. Allen and J. S. Rinehart, *Rev. Sci. Instr.*, *22:* 1020, Dec. 1951.

Étude Photographique de la Combustion d'un Cordeau Detonant, P. Libessart, *Sci. Ind. Phot.* (2), *23:* 14–16, Jan. 1952.

Phenomena Associated With the Flight of Ultra-Speed Pellets. Pt. II. Spectral Character of Luminosity, W. C. White, J. S. Rinehart and W. A. Allen, *J. Appl. Sci.*, *23:* 198–201, Feb. 1952.

An Investigation of Cracks and Stress Waves in Glass and Plastics by High-Speed Photography, D. G. Christie, *J. Soc. Glass Tech.*, *36:* 74–89, Feb. 1952. (*Photographs from 20,000 to 200,000 frames/sec.*)

Shot on the Wing, *U.S. Camera*, *15:* 38–39, 107, Mar. 1952.

Techniques for Effective High-Speed Photography and Analysis, R. O. Painter, *Jour. SMPTE*, *58:* 373–384, May, Pt. I, 1952.

Ballistics Photography Uses Mobile Flash, E. C. Barkofsky, *Electronics*, *25:* 128–30, June 1952.

Birth of a Flame, M. Lorant, *Functional Phot.*, *3:* 19, June 1952. (*Schlieren photography of a flame from 5.8 to 1,112 millionths of a second old. Work done by H. L. Olsen, R. B. Edmonson and E. L. Gayhart at the Applied Physics Laboratory, Johns Hopkins University.*)

Use of a Rotating-Drum Camera for Recording Impact Loading Deformations, D. F. Muster and E. G. Volterra, *Jour. SMPTE*, *59:* 44–48, July 1952.

Photography at Sea of Ship-Propeller Cavitation, J. W. Fisher, *Trans. N. E. Coast Institution Engineers and Shipbuilders*, *68:* 20–30, Oct. 1951.

Underwater Observation and Photography of Flow Phenomena through Glass Panels in a Ship's Hull, J. W. Fisher, *Nature*, *169:* 1074–1076, June 28, 1952.

Film Studies of Armament, A.R. Michaelis, *Quarterly of Film, Radio and Television*, *6:* 235–240, #3, 1952.

Preliminary Investigation of the Use of Afterglow for Visualizing Low-Density Compressible Flows, T. W. Williams and J. M. Benson, *NACA TN* 1900, June 1949.

Étudo du Mouvement des Projectiles per la Photographie Instantanée, A. Rateau, *Actes Coll. inter. Mecan. II, Publ. sci. tech. Min. Air, Paris, #250:* 73–80, 1951. (*Angle which the axis of a projectile while in flight makes with trajectory is determined photographically by two simultaneous stereoscopic pictures. Exposure around 1 μsec.*)

An Improved Technique for High-Speed Photography, D. A. Senior and C. O. J. Cove-Palmer, *Brit. J. Appl. Phys., 3:* 318–321, Oct. 1952.

Electro-Optical Shutters as Applied to the Study of Electrical Discharges, J. Meek and R. C. Turnock, *Phot. J., 92B:* 161–166, Sept.-Oct. 1952.

Nature Photography with the High-Speed Flash, W. Van Riper, R. J. Niedrach and A. M. Bailey, Denver, Colorado, Denver Museum of Natural History. 64 pp. Chiefly illustrations. (Issue #5 of Museum Pictorial.)

High-Speed Photography: Steel Research Tool, R. A. Buchanan, *Steel, 131:* 90–91, July 7, 1952.

Photography Helps Develop Rockets and Guided Missiles, R. W. Herman, *PSA Jour. (Phot. Sci. Tech.), 18B:* 107–111, Dec. 1952.

We Break 'Em to Make 'Em Better, *Industrial Photography, 1:* 42–43, Fall 1952. (*Service testing with high-speed cinematography.*)

Flash Photography, R. Connolly, *Camera Mag., 76:* 49–66, Feb. 1953.

Synchro-Flash Photography, G. L. Wakefield and N. W. Smith. Fountain Press, London. 3rd ed. 1952.

Investigation of Annular Liquid Flow With Cocurrent Air Flow in Horizontal Tubes, A. E. Abramson, *J. Appl. Mech., 19:* 267–274, Sept. 1952.

Some Current Image Converter Practice, R. F. Laurence and K. Shaftan, *Phot. Eng., 3:* 189–206, #4, 1952.

A Study of Droplet Behaviour in Packed Columns, J. B. Lewis, I. Jones and H. R. C. Pratt, *Trans. Inst. Chem. Eng., 29:* 126–144, $1, 1951. (*Photographs of the droplets and details of the apparatus.*)

High-Speed Cine-Electrocardiography, J. J. Fields, L. Fields, E. Gerlach and M. Prinzmetal, *Jour. SMPTE, 59:* 493–497, Dec. 1952.

Optical Aids for High-Speed Photography, D. C. Gilkeson and A. E. Turula, *Jour. SMPTE, 59:* 498–502, Dec. 1952.

The Electronic Camera in Film-Making, N. Collins and T. C. MacNamara, *Jour. SMPTE, 59:* 445–462, Dec. 1952.

Motion Photography for Combustion Research, F. W. Bowditch, *Jour. SMPTE, 59:* 472–484, Dec. 1952.

Accuracy Limitations on High-speed Metric Photography, A. E. Griffin and E. E. Green, *Jour. SMPTE, 59:* 485–492, Dec. 1952.

Application of High Speed Flash Tube to Photographing the Fundus of the Eye in Color, M. Jacobs and K. N. Ogle, *Rev. Sci. Instr., 24:* 52–55, Jan. 1953.

Flame Photography, R. B. Konikow, *Industrial Phot., 2:* 26–29, Jan. 1953.

Motion Picture and Flash Photography in Mechanics Research, C. C. Hauver, *PSA Jour. (Phot. Sci. Tech.), 19B, #1:* 27–29, Feb. 1953.

High-Speed Photography in Medicine, J. H. Waddell, *PSA Jour. (Phot. Sci. Tech.), 19B:* #1, 29–31, Feb. 1953.

Time-Resolved Spectroscopy of Ultra-speed Pellet Luminosity, W. A. Allen and E. B. Mayfield, *J. Appl. Phys., 24:* 131–133, Feb. 1953. (*Illustration of the single drum camera and spectrograph attachment, also a fast shutter and high-voltage switch arrangement.*)

High-Speed Photographic Techniques for the Study of the Welding Arc, I. L. Stern and J. H. Foster, *Jour. SMPTE, 60:* 400–404, Apr. 1953.

Use of Photography in the Underground Explosion Test Program, 1951–1952, R. M. Blunt, *Jour. SMPTE, 60:* 405–417, #4, Pt. 1, 1953.

Microsecond Photography of Rocket in Flight, E. Barkofsky, R. Hopkins and S. Dorsey, *Electronics, 26*: 142–147, June 1953. (*Electronically controlled flashlamps use in connection with 46 precision ballistics cameras.*)

Kinematographie von Gleitlinien auf Al-Einkristallen, R. Becker and P. Haasen, *Acta Metallurgica, 1:* 325–335, May 1953.

Photomicrography of Moving Specimens, B. A. Jarrett, *J. Phot. Sci., 1:* 97–108, May/June 1953.

Applications of High-Speed Photography in Rocket Motor Research, F. G. Stratton and K. R. Stehling, *Jour. SMPTE, 60:* 597–602, May 1953.

Combustion, F. T. McClure and W. G. Berl, *Ind. Eng. Chem.*, **45**: 1415–1425, July 1953. (*Contains illustrations of turbulent natural gas-air flame, and composite drum camera record of flame propagation in a tube containing a* **10%** *methane-air mixture.*)

Application of Image Converters to High Speed Photography, J. A. Jenkins and R. A. Chippendale, *J. Brit. Inst. Radio Eng., 11:* 505–517, Nov. 1951.

High Speed Photography: Steel Research Tool, R. A. Buchanan, *Steel, 131:* 90–91, July 7, 1952.

Ballistics Photography Uses, Mobile Flash, E. C. Barkofsky, *Electronics, 25:* 128–130, June 1952.

VII. X-RAY

The Applications of Radar Techniques to a System for High-Speed X-ray Motion Pictures, D. Dickson, C. Zavales and L. F. Ehrke, *Proc. Natl. Electronics Conf., 4:* 298–313, Nov. 1948.

X-Ray Motion Picture Techniques Employed in Medical Diagnosis and Research, S. A. Weinberg, J. S. Watson, Jr., and G. H. Ramsey, *Jour. SMPTE, 59:* 300–308, Oct. 1952.

X-Ray Motion Picture Camera and Printer for 70mm Film, S. A. Weinberg, J. S. Watson, Jr., and G. H. Ramsey, *Jour. SMPTE, 60:* 31–37, Jan. 1953.

Book Notes

Due to circumstances beyond our control the Society has been unable to obtain timely reviews of two high-speed photography books. The bibliographical data and contents are as follows:

The Photographic Study of Rapid Events

By W. D. Chesterman. Published (1951) by Oxford University Press, 114 Fifth Ave., New York 11, N.Y. 168 + i–xiii + 32 pp. plates. $4.25.

The book is divided into two parts, Part I covering "The Techniques Used" and Part II covering "The Application of the Techniques." Part I consists of the following chapter titles:

Ch. I — Classification of Techniques
Ch. II — Intermediate Rate Cameras
Ch. III — Lighting the Event
Ch. IV — Choice of Sensitive Material
Ch. V — Single Pictures
Ch. VI — Film Drum Cameras
Ch. VII — Spark and Schlieren Photography

Part II contains the following chapters:

Ch. VIII — Zoological Studies
Ch. IX — Biological and Medical Sciences
Ch. X — Physical and Engineering Research
Ch. XI — Military Applications
Ch. XII — Conclusion

High Speed Photography: Its Principles and Applications

By George A. Jones. Published (1953) by John Wiley & Sons, 440 4th Ave., New York 16, N.Y. i–xvi + 311 pp. 118 illus. $5\frac{1}{4} \times 8\frac{1}{4}$ in. $4.50.

Ch. I — Introduction and History
Ch. II — The Production of Short Flashes
Ch. III — High Speed Cinematograph Camera Design
Ch. IV — Photographic Materials
Ch. V — High Speed Still Photography
Ch. VI — High Speed Cinematograph Cameras
Ch. VII — Cinematographic Technique
Ch. VIII — Trace Recording Cameras
Ch. IX — Picture-Making Recording Cameras
Ch. X — Scientific Applications of High Speed Photography
Ch. XI — Industrial and Commercial Applications
Appendixes A–C: High-Speed Cameras; Gas-Discharge Flash Tubes; Formulae

Engineering Activities

The number of projects in work, number and frequency of committee meetings and the attendance at these meetings are all useful clues to the volume of engineering work undertaken by the Society and to the relative importance to engineers and to the trade of results now being turned out. That this year's technical activities measure up on all counts will be attested to by the members of more than half the Society's engineering committees who attended some 25 hours of official meetings during the 74th Convention and thereby set some sort of record. Their accomplishments are briefly reviewed below.

Color: The scope of its two dormant subcommittees on (1) Projection Light Sources and Screens for Color Films, and (2) Spectral Energy Distribution of Photographic Illuminants was reviewed, and the decision was made to reactivate the subcommittees.

A new subcommittee was formed to prepare a color film exposure guide monograph for use by studio operating personnel.

Film Dimensions: This Committee was concerned primarily with 35mm film perforations for CinemaScope and decided to initiate standardization procedures. Material is now being assembled for a tentative standard and the committee would welcome any comments or questions from members and nonmembers alike.

Film Projection Practice: An energetic program of revising three existing standards was undertaken. These standards are: Projection Lenses for Motion Picture Theaters, Z22.28-1946; 35mm Projector Sprockets, Z22.35-1947; and Projector Reels for 35mm Film, Z22.4-1941. The scope of the latter standard is now being broadened to include both reels and magazines.

Films for Television: A small attendance permitted this group to have the distinction of being the only committee to meet in the RCA Coffee Club. Despite (or possibly because of) the informality, excellent coffee and buns, headway was made on two important projects: (1) Steps were taken to initiate standardization of the Society Synchronizing Leader. It is hoped that this leader will eventually be used both for theaters and television. (2) It was agreed to form a subcommittee to prepare the specifications and speed the development of a color television test film.

Laboratory Practice: This group continued its heavy standardization program. Letter ballots and draft standards on 16mm review-room screen brightness and on printer light change cuing are being or will shortly be circulated to the full committee. In addition, further action was recommended on revision of one standard, Sound Records and Scanning Area of 16mm Sound Motion Picture Prints, Z22.41-1946. Reaffirmation was recommended for two standards: Printer Aperture Dimensions for Contact Printing 16mm Positive Prints From 16mm Negatives, Z22.48-1946; and Printer Aperture Dimensions for Contact Printing 16mm Reversal and Color Reversal Duplicate Prints, Z22.49-1946.

Screen Brightness: Reports were heard from the four Subcommittees. The Subcommittee on Meters and Methods of Measurements was then disbanded since it had completed its assigned project (published in the October 1953 *Journal*). The question of 16mm review room screen brightness was also reviewed by this group and the same letter ballot will be circulated to both the Laboratory Practice and Screen Brightness Committees.

16mm and 8mm Motion Pictures: Revision of Z22.15-1946, and Z22.16-1947, 16mm Film Perforated One Edge — Usage in Camera and Projector, has been in the works for over a year, with the edge guiding question the only stumbling block. This question was thoroughly reviewed and a compromise solution was reached. This solution also affects the two standards on apertures, Z22.7-1950 and Z22.8-1950, where edge guiding is similarly involved. The chosen procedure is to delete the guided edge specification from all four standards and instead to prepare a Society Recommended Practice on the history, factors and trend in the edge guiding of 16mm film perforated one edge.

Revision of Z22.9-1946 and Z22.10-1947, 16mm Film Perforated Two Edges — Usage in Camera and Projector, has been stymied by another thorny question, the frame rate. It is fairly well agreed that the camera should run at nominally 16 frames/sec. The difference was primarily in part of the group insisting on a projector rate of 18 frames/sec and the other part wanting to retain a rate of 16 frames/sec. This question was not resolved; however, it was agreed that both groups would thoroughly document their positions in an effort to resolve the question at the next meeting, during the 75th Convention.

The proposed standard on a new Travel Ghost Test Film also came in for debate. Further action was tabled on this proposal until the committee has an opportunity to consider a counter proposal soon to be submitted by RCA.

Without controversy it was agreed: (1) to establish liaison with ASA Sectional Committee C81 on standardization of medium prefocus lamp sockets, (2) to investigate the possibility of the Society's producing a test film for 8mm projectors and (3) to form a subcommittee to study and possibly initiate standards on reels for television use, both in the 600-ft and over 2000-ft size.

Sound Committee: Discussion relating to standards was limited to two proposals: (1) 16mm Buzz Track Test Film, Z22.57-1947 — this was modified slightly and approved for further processing by the Standards Committee. (2) Magnetic Sound Specifications, 16mm Film Perforated Two Edges, SMPTE 626 — here the ±2-frame tolerance on the 26-frame separation of picture and sound was considered excessive and the proposal was returned to the Magnetic Recording Subcommittee for reconsideration.

The balance of the meeting was devoted to questions related to four-track stereophonic sound and required test films. Responsibility was assigned for drawing up manufacturing specifications for several types of four-track test films.

Magnetic Recording: This subcommittee of the Sound Committee recorded appreciable progress at this meeting. Agreement was reached on the common use of a 16mm Multifrequency Test Film supplied by the Society to determine the various projector sound-reproduce characteristics. It is expected that this will lead to the standardization of a common characteristic.

Two proposals on half-magnetic and half-photographic sound track, differing solely in the width of the magnetic stripe, had been under consideration. This was narrowed down to one (53-mil stripe) for letter ballot of the entire subcommittee.

A second draft of the proposal "200-mil Magnetic Sound Track on 16mm Film Perforated One Edge" was also approved for letter ballot.

Track placement and reproduce characteristics of four-track stereophonic sound was discussed and responsibility assigned for preparation of initial standards proposals.

Television Film Equipment: The principal purpose for calling this meeting was to resolve a conflict which had developed on one section of the 16mm Television Projector Standard, PH22.91. The disputed item concerned the length of the illumination pulse, whether the shutter pulse should be made 7% of the vertical blanking period or remain 5%. A compromise value of 6.5% was finally reached and found acceptable by all. With this question resolved, it will now be possible to continue processing of this standard in ASA Sectional Committee PH22.

Theater Engineering: The agenda was limited to consideration of a committee report providing an analysis of the Theater Screen Survey inaugurated by the committee in May 1953. The report, prepared by Ben Schlanger, Committee Chairman, was reviewed and the general outline approved after some modification. This report was subsequently presented to the Convention and will be published in a later issue of the *Journal.*

Stereoscopic Motion Pictures: Drafts of a bibliography and a nomenclature were reviewed. Both require additional work before publication is possible and plans were made to speed this activity. Two proposed standards were approved for letter ballot of the full committee. These specified: (1) the transmission characteristic of polarizing filters, and (2) where the left- and right-eye image lenses are not of exactly equal focal length, the longer focal length lens shall be used on the left-eye lens in all cases.—*Henry Kogel,* Staff Engineer.

Board of Governors Meeting

The Board on October 4 reviewed the Society's overall activities which are summarized in the Executive Secretary's report given below. Other matters and actions are here reported briefly:

After reports by Financial Vice-President Cahill and Treasurer Kreuzer and formal approvals of banking arrangements, attention was devoted to the Society's test film program services and expenses.

The name of the Test Film Quality Committee was changed to "Test Film Committee," and this Committee was charged with surveying the need for additional test films, and with reporting to the Engineering Vice-President on test film technical matters including suitability of all proposed new test film specifications and standards that originate within the other engineering committees.

E. S. Seeley, Secretary, advised the Board that the basic outline for the new Administrative Practices drawn up by Headquarters and Counsel had been submitted to him and that work was progressing. He also reported the results of the Society's national election for 1953. These and the Section's election results are given separately in this *Journal.*

J. W. Servies, Convention Vice-President, reported that plans for the 74th Convention had been completed. Registration fees, he said had been rescaled to favor members who would continue to pay $5.00 weekly and $2.00 daily fees, while nonmembers would be charged $7.50 and $2.50. Luncheon tickets were $4.00 per person and tickets for the Cocktail Party–Banquet were $12.50 per person, the same as charged at the 73d Convention.

A break from the custom of SMPTE award presentation during the midweek banquet of the fall convention each year had for some time been considered desirable by many members. As an attempt at a more appropriate setting for the award ceremony, the convention schedule was arranged with a formal awards session in place of the Monday night technical papers.

Exhibits, previously considered and carefully studied following the July meeting, were ruled out for the 74th Convention, by Mr. Servies, because time did not permit proper arrangement. Exhibits at subsequent conventions were discussed at length with a free expression of differing opinions, some favoring formal trade show exhibitions planned and managed by the Society, others opposing on the grounds that the theater equipment market was already well served by established shows, that television and electronics interests were ably satisfied by exhibitions of NARTB, IRE, National Electronics Conference, Radio-Parts show and the Audio Fairs, and that the areas of SMPTE interest not served thus far — laboratory equipment, specialized studio equipment and perhaps lighting equipment were all that would benefit. A suggestion that exhibits be held regularly with SMPTE Conventions was not approved.

Mr. Servies reported he had made plans to publish on Tuesday morning of convention week, a mimeographed list of Sunday and Monday registrants and that a supplement would be issued Wednesday.

The report of Engineering Vice-President Hood summarized the extensive engineering activities which are reflected in the reports and standards published continuously in the *Journal.* Standards approved by the Board of Governors will appear in the *Journal* as soon as they have ASA authorization.

Editorial Vice-President Simmons described program plans for the 74th Convention, and reported upon the current status of the *Journal.* Special plans for the 75th Convention were also reviewed, with information supplied by John Frayne, Chairman of the special committee for original plans for that Convention.

Gordon A. Chambers, Chairman of the Awards Study Committee, told of the approach taken by his group and of progress made to date. A draft of recommendations was submitted to individual Board Members for their study, with the request that reactions and suggestions be sent direct to Chairman Chambers for consideration by the Committee. The Board asked that this Committee include the Journal Award, this heretofore not having been formally included in the Committee's task. It is planned to publish the entire awards procedures as crystallized by this Committee in the April *Journal.*

Report of the Executive Secretary

Membership: New members admitted during the first nine months of 1953 reached 913, an all-time high. Delinquents, by the end of the same period, had been pushed down to the record low of 272. Net change for the period was 17 per cent. This is a net increase of 641 members, the best yet. There is an outside chance that the official year-end target, a net increase of 1000 members, will be reached.

Journal: The first nine *Journals* for 1953 contained six more pages than were published during the entire preceding year. Of these nine issues that add up to 1214 pages, three were in two parts. Part II for April was on magnetic striping, the second part for August covered screen brightness, and in the special issue for September, stereo sound was featured. Manuscripts now assured or on hand will fill three 125-page issues for October, November and December, each to contain a respectable subject grouping of articles. Contents for the two final months will have been derived primarily from the October convention. Because papers procurement efforts have continued to be very effective, additional "Part-two's" are planned for 1954.

Test Films: Quality control efforts by the Society's test film engineer continue to roll up a good record for the reliability of this valuable direct service to companies and individuals in both motion pictures and television. Demand for magnetic test films increases steadily. Present service, however, does not go far enough because the Society has had little success in finding suitable, reliable sources for some of the more essential 16mm films, but extensive efforts are being made to keep up with new film requirements without neglecting the ever increasing volume of requests for advice and technical assistance precipitated by the widespread adoption of new motion-picture and television techniques.

One special project now receiving attention is development of a special short version 16mm film for Navy projectionists. Early approval and volume production of the film during the fourth quarter are expected. Sales for the first three quarters lag 23% behind the target figure for the period and will doubtless be similarly behind at year end.

Engineering: The recent appearance of stereo sound and wide-screen and stereo picture systems has brought a pressing requirement for SMPTE attention to practical problems encountered in the installation and operation of these systems in theaters.

In addition, equipment people are seeking help with standards. This is also true in the field of 16mm motion pictures and magnetic recording. The most recent shifts of emphasis are reflected in the current list of items now being worked upon by committees and by the Headquarters staff.

One area long in need of attention but short on receipt of it is educational motion pictures. What of a practical nature can be done is not quite certain but the question must soon be cleared up so that SMPTE can answer a request for assistance that will shortly be forthcoming from NAVA.

Public Relations: A practical service to education of future motion-picture business and technical people is provided by SMPTE members who are active in the work of the USC Student Chapter, and by four in particular who took part in the National Conference of the University Film Producers Association held at USC in August. Another useful service was the Society's exhibit at the NAVA convention in Chicago.

Trade and daily press use of Society news releases has been both generous and sympathetic, but the Society has not sold itself effectively in all directions. Television is one publicity problem-area and those phases of our current work need further attention.

Another problem-area is exhibition. Although individual exhibitors or small-circuit owners may never develop an abiding interest in the Society, they should be well enough posted on how our work relates to exhibition so that recommendations, reports or standards that have theater application will find ready use.

New Officers

The results of the Society's election were announced at the Board of Governors Meeting on October 4, 1953, by Secretary Edward S. Seeley. The following were elected for two-year terms beginning January 1, 1954:

Axel G. Jensen, Engineering Vice-President
Barton Kreuzer, Financial Vice-President
Geo. W. Colburn, Treasurer
Frank N. Gillette, Governor, East
Lorin D. Grignon, Governor, West
Ralph E. Lovell, Governor, West
Garland C. Misener, Governor, East
Richard O. Painter, Governor, Central
Reid H. Ray, Governor, Central

In the Section elections, the following officers were elected for one-year terms, and new members of the Section Boards of Managers for two-year terms.

Atlantic Coast Section

John G. Stott, Chairman
Everett Miller, Secretary-Treasurer
George H. Gordon, Manager
George Lewin, Manager
J. Paul Weiss, Manager

Central Section

James L. Wassell, Chairman
Kenneth M. Mason, Secretary-Treasurer
Howard H. Brauer, Manager
George Ives, Manager
Henry Ushijima, Manager

Pacific Coast Section

Philip G. Caldwell, Chairman
Edwin W. Templin, Secretary-Treasurer
C. N. Batsel, Manager
Sidney Solow, Manager
Robert Young, Manager

Southwest Subsection

Ira L. Miller, Jr., Chairman
Walter W. Gilreath, Secretary-Treasurer
John H. Adams, Manager
Hervey Gardenshire, Manager
Hugh V. Jamieson, Sr., Manager
Donald Macon, Manager

Pacific Coast Section Meetings

Following a two-month summer hiatus, the Pacific Coast Section of the SMPTE met on September 22, 1953, at the Metro-Goldwyn-Mayer Pictures Studio in Culver City. The program subject for the evening was "3-D and Wide-Screen at M-G-M."

Because of the limited seating capacity on the sound stage at M-G-M, the attendance at the meeting had to be confined to two sessions allowing two hundred members each. Members were asked to telephone their reservations for attendance at the meetings, and were admitted by a show of membership card.

The program consisted of a presentation of 3-D and wide-screen techniques as they are being studied and used in production at a major Hollywood studio. An appraisal of the boxoffice value of the various new techniques and demonstrations from current productions made in Hollywood and England combined to make this an unusually timely and interesting program. Douglas Shearer, Director of Recording for M-G-M Pictures, lent invaluable assistance in planning the meeting. However, due to illness, Mr. Shearer was unable to attend, and Frank Milton, Mr. Shearer's assistant, presided for the evening. The film demonstrations of the engineering problems confronting the industry, as it considers CinemaScope, wide-screen, 3-D, different aspect ratios and stereophonic sound, were well planned and executed.

The meeting was particularly impressed by the thoroughness of M-G-M's policy in approaching the practical problem of triple-type theater film entertainment in the form of pictures in CinemaScope, wide-screen and 3-D in such a manner as to meet the maximum possible demand from the exhibitor. The excellent color quality of the daily rush prints reflected the progressive attitude in keeping in stride with latest color film developments.

There was an extensive and lively question and answer period after each of the two sessions.—*Philip G. Caldwell*, Secretary-Treasurer, Pacific Coast Section.

75th Semiannual Convention

Joe Aiken, Program Chairman for the 75th Convention at the Hotel Statler in Washington, D.C., May 3–7, has released a tentative roster of sessions based upon the special activities for this program, reported in the last *Journal.* Some papers have been added and technical sessions and, during a recent visit by Convention Vice-President Jack Servies, entertainment features were arranged according to hotel facilities. This is the tentative outline of the week's activities, subject to probable revision when the Author Forms are all in:

Monday Noon — Get-Together Luncheon
Monday Afternoon — "Professional 35mm Camera" by C. E. Phillimore
Monday Evening — "Black-and-White Cinematography" by C. E. K. Mees
Tuesday Morning — "35mm Projector" by R. Mathews and Willy Borberg
"The Evolution of Motion-Picture Theaters" by Ben Schlanger
Tuesday Afternoon — "Color Cinematography" by Gerald F. Rackett
Tuesday Evening — Pioneers' Dinner
Wednesday Morning — "Sound" by E. W. Kellogg
"Motion-Picture Lighting" by Charles W. Handley
Wednesday Afternoon — "16mm Camera and Projector" by Malcolm G. Townsley
Wednesday Evening — at the National Archives:
"Evolution of Motion-Picture Techniques" by James Card
"Matthew B. Brady" by Josephine Cobb
Thursday Morning — "Early Development of the 16mm Reversal Process" by Glenn E. Matthews and R. G. Tarkington
Thursday Afternoon — "The Motion-Picture Laboratory" by John I. Crabtree
Thursday Evening — Cocktail Hour and Dinner-Dance
Friday Morning — "The Photography of Motion" by Morton Sultanoff and John Waddell
"History of the Electronic Flash" by Harry Parker
Friday Afternoon — "Mechanical Television" by J. V. L. Hogan
"Electronic Television" by Axel G. Jensen

Most of the above papers will be about an hour in length. On each session there will be briefer papers about current developments in the industry, that is, the type of paper which usually makes up the substance of the program. The Papers Committee, listed in full in the November *Journal*, now has Author Forms and any member will welcome word about prospective papers.

Central Section Meeting

The Section held an all-day meeting on Friday, September 11, in Dayton, Ohio. At the morning session, which took place at Station WLW-D, Neal VanElls, Program Director of WLW-D, spoke on "TV Production Techniques," and Lester G. Sturgill, WLW-D's Chief Engineer, discussed "Problems in Transmission of Color TV."

For the afternoon session the meeting moved to the Wright Air Development Center, Air Research and Development Command, where two papers were read: "Electronic Viewer for Aerial Photographs," by Richard O. Eaton, Project Engineer of WADC-ARDC; and "16mm and 35mm Processing Equipment vs $9\frac{1}{2} \times 18\frac{1}{2}$ in. Processing Equipment," by R. D. Fullerton, Chief, Processing Equipment Section, WADC-ARDC. Members were given a demonstration of new reconnaissance equipment by means of stereo slides of terrain in Korea, and the reconnaissance equipment itself was available for inspection.

This program and facilities for it were arranged by Mrs. Jane Bernier, Synthetic Vision Corp., Dayton, Ohio.

Awards

The various honors awarded annually by the Society for outstanding achievements and contributions were presented during the Fall Convention in New York.

The general description of these awards, together with the names of all previous recipients, was published earlier this year, in the April *Journal*.

Journal Award

The Society's Journal Award, for the best paper published in the *Journal* during 1952, was shared by R. J. Spottiswoode, N. L. Spottiswoode and Charles Smith for their paper "Basic Principles of the Three-Dimensional Film" (October).

Honorable mention for outstanding papers was given to:

Willy Borberg, "Modulated Air Blast for Reducing Film Buckle" (August);

C. R. Carpenter and L. P. Greenhill, "A Scientific Approach to Informational-Instructional Film Production and Utilization" (May);

G. C. Higgins and L. A. Jones, "The Nature and Evaluation of the Sharpness of Photographic Images" (April);

Otto H. Schade, "Image Gradation, Graininess and Sharpness in Television and Motion-Picture Systems — Part II: The Grain Structure of Motion-Picture Images" (March); and

Norman Collins and T. C. MacNamara, "The Electronic Camera in Film-Making" (December).

Samuel L. Warner Memorial Award

W. W. Wetzel, of the Minnesota Mining and Mfg. Co., St. Paul, Minn., received the Samual L. Warner Memorial Award medal.

The citation for this award, read by Wallace V. Wolfe, Chairman of the Committee, was: "Dr. Wetzel has made recent noteworthy contributions to the development of excellent magnetic tapes and films now commercially available. Their improvement constitutes a step necessary to the widespread use of magnetic sound recording in the motion-picture industry."

David Sarnoff Gold Medal Award

Arthur V. Loughren, of the Hazeltine Corp., Little Neck, L. I., N. Y., was presented with the David Sarnoff Gold Medal Award by Loren L. Ryder, Chairman of the awarding committee. Mr. Loughren's service to the industry was cited as follows:

"For his contributions to the development of compatible color television including his active work on the principle of constant luminance adopted as part of the signal specifications of the National Television System Committee.

"For his participation in the work of the NTSC as Chairman of Panel 13, Color Video Standards.

"For his important contributions as a guiding spirit and forceful exponent of compatible color television, and for his simple mathematical expression and lucid description of the aims and accomplishments of the NTSC, prepared and published for the orientation of engineers working in that field."

Progress Medal

The Society's highest honor, the Progress Medal, was given to Fred Waller, President of Vitarama Company and Chairman of the Board of Directors of Cinerama, Inc., for "putting to practical use the peripheral vision phenomenon." David B. Joy, Chairman of the Progress Medal Award Committee, made the formal presentation and spoke of Fred Waller's work as follows:

"Fred Waller, in 1905, first entered the motion-picture field as a creator of lobby displays. From that time on, he has been deeply involved in the artistic and technical progress and development of the industry. His experiences include studio special effects, photographic research, optical printer design, and motion-picture production and direction. His interests cover other wide fields of endeavor. He has more than 50 patents ranging in diversity from optical printers to water skis.

"In 1938, just prior to the New York World's Fair, Waller organized a group for developing a concave screen process. For the Fair itself, he produced the motion pictures of the figures on the inside of the Perisphere and planned the Eastman Kodak Hall of Color demonstration. In fact, he built his first model of Cinerama hoping to sell it to one of the Fair's exhibitors, but his invention was considered too radical.

"He did apply this principle to the Waller Gunnery Trainer. This used five films projected simultaneously onto a spherical screen to show planes flying in imitation of battle conditions. This Trainer was used by the British and American Armed Forces and was said to have prevented thousands of casualties.

"Continuing in his faith that this curved screen process utilizing the effect of peripheral vision had entertainment value as well as utility in war, he set up a research laboratory on Long Island to continue his experiments.

"In 1946, he began to build the demonstration apparatus of the Cinerama process which he was to use in the public theater. Many new motion-picture tools had to be constructed for both taking and projecting simultaneously the three picture components. The screen itself was a special development made of overlapping strips of perforated plastic ribbon and spread over an arc of approximately 145°. His first private demonstration, staged in an indoor tennis court, was in 1949. This aroused great interest and controversy as to whether it would be as spectacular when viewed in a large theater.

"The finished product had its first public theater showing in September 1952. The reaction of the public is well known.

"Waller's work, and its reception by the public, has stimulated and intensified development, engineering and exploitation activity throughout the motion-picture industry. It has encouraged the industry and the public itself to look for and try out modifications in motion-picture photography and projection which had been thought heretofore too radical to consider.

"The Committee was unanimous in its decision that Fred Waller in his inventions, development and persistant faith in the possibilities of the peripheral vision phenomenon, has fully earned the recognition accorded him by this Award. This action of the Committee is in no way to be taken as an endorsement of any particular system of motion-picture presentation. It is a recognition of the accomplishments of the man himself and the tremendous catalytic effect on the rest of the industry."

New Fellows of the Society

On Wednesday evening, President Barnett inducted the following as new Fellows of the Society. The award was made posthumously to Kenneth Shaftan.

Merle H. Chamberlin, Metro-Goldwyn-Mayer Studios, Culver City, Calif.
LeRoy M. Dearing, Technicolor Motion Picture Corp., Hollywood, Calif.
Russell O. Drew, RCA Victor Division, Camden, N. J.
Carlos H. Elmer, U. S. Naval Ordnance Test Station, China Lake, Calif.
Frank N. Gillette, General Precision Laboratory, Pleasantville, N. Y.
Gerald G. Graham, National Film Board of Canada, Ottawa, Ontario, Canada
Sol Halprin, Twentieth Century-Fox Films, Los Angeles, Calif.
A. V. Loughren, Hazeltine Corp., Great Neck, N. Y.
Ralph E. Lovell, National Broadcasting Co., Los Angeles, Calif.

Arthur J. Miller, Consolidated Film Industries, Fort Lee, N.J.
John W. Servies, National Theatre Supply, New York, N.Y.
Kenneth Shaftan, J. A. Maurer, Inc., New York, N.Y.
Raymond J. Spottiswoode, Stereo Techniques, Ltd., London, England
Charles L. Townsend, National Broadcasting Co., New York, N.Y.
T. G. Veal, Eastman Kodak Co., Rochester, N.Y.

Current Literature

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

vol. 34, Aug. 1953

The Motion Picture Research Council 3-D Calculator (p. 373) *A. J. Hill*
3-D in Industrial Film Production (p. 374) *B. Howard*
Covering Spot News for Television (p. 378) *R. Renick*

vol. 34, Sept. 1953

A Stereo Camera for Two-Strip 16mm 3-D Photography (p. 428) *F. Foster*
Cinepanoramic—New French Anamorphic Lens (p. 434) *A. Rowan*
Wide Screen for 16mm Movies (p. 436) *J. Forbes*

Audio Engineering

vol. 37, Sept. 1953

A New Volume Visualizer (p. 30) *N. Prisament*
Handbook of Sound Reproduction. The Power Amplifier. Chapter 12, Pt. 3 (p. 36) *E. M. Villchur*

Bild und Ton

vol. 6, July 1953

Die Leistungsgrenzen der Fotoapparate (p. 195) *E. Hüttman*
Ein neuer Densograph (p. 212) *A. Erlenbach*

British Kinematography

vol. 23, July 1953

The Presidential Address (British Kinematograph Society) (p. 8) *B. Henri*
The Use of Film in Television Production (p. 13) *I. Atkins*

vol. 23, Aug. 1953

Process Projection in Colour
- Pt. 1. Introduction and Physical Aspects (p. 33) *R. L. Hoult*
- Pt. 2. The Preparation of Colour Plates for Still Projection (p. 36) *M. E. Harper*
- Pt. 3. Process Projection Equipment and Techniques Required for Colour Films (p. 38) *C. D. Staffell*

Some Notes on the British Standard of Screen Luminance (p. 43) *F. S. Hawkins*

Electronics

vol. 26, Oct. 1953

Television Monitors Rocket Engine Flame (p. 187) *F. A. Friswold*

Das Film-Technikum

vol. 4, Sept. 1953

Erste CinemaScope-Vorführung in Deutschland (p. 194)
Französisches Panoramaverfahren "Sonoptik" (p. 198)
"Wide Screen" verursacht Normenkrise (p. 199) *W. Gründorf*
Anamorphotische Optik für Kino-Breitschirmprojektion (p. 201)

Home Movies and Cine Photographer

vol. 20, Sept. 1953

16mm Wide Screen Available Now (p. 358)

Institution of Electrical Engineers, Proceedings

vol. 100, Pt. 1, Sept. 1953

Special Effects for Television Studio Productions (p. 288) *A. M. Spooner and T. Worswick*

International Photographer

vol. 25, Sept. 1953

Dark Thoughts on the New (p. 5) *J. T. de Kay*
16mm 3-D Camera (p. 8) *F. A. Parrish*
The Superscreen is Here to Stay (p. 12) *C. W. Dudley*

International Projectionist

vol. 28, Aug. 1953

Stereoscopic Projection and Photography (p. 5) *R. A. Mitchell*
Converting Theatres for CinemaScope (p. 11)

vol. 28, Sept. 1953

Does CinemaScope Have the Answer? (p. 5) *T. L. Burnside*
Stereoscopic Projection and Photography (p. 9) *R. A. Mitchell*
Color TV...and How it Works! (p. 14) *J. Morris*
How to Check for—and Get—Maximum Light at the Screen (p. 16)

Motion Picture Herald

vol. 193, Oct. 10, 1953

Theatre Built for 3-D and Wide-Screen (p. 14)

Sizing the Picture for "Wide-Screen" (p. 16) *B. Schlanger*

Functional Lighting of Auditoriums (p. 20) *S. McCandless*

Philips Technical Review

vol. 15, No. 1, July 1953

A Large-Screen Television Projector (p. 27) *J. Haantjes and C. J. van Loon*

Photo-Technik und Wirtschaft

vol. 4, Oct. 1953

Exakte oszillographische Messungen der Arbeitsweise von Kamera-Synchronkontakten (p. 392) *J. Czech*

Radio and Television News (Radio-Electronic Engineering Edition)

vol. 50, Sept. 1953

Visual Proof of Performance Measurements (p. 14) *R. D. Chipp*

Looking at Tubes. Picture Reproducing Tubes for Color Television (p. 22) *W. B. Whalley*

RCA Review

vol. 14, Sept. 1953

A VHF-UHF Television Turret Tuner (p. 318) *T. Muramaki*

A Comparison of Monochrome and Color Television with Reference to Susceptibility to Various Types of Interference (p. 341) *G. L. Fredendall*

Technical Signal Specifications Proposed as Standards for Color Television (p. 359)

Tele-Tech

vol. 12, Sept. 1953

Final NTSC Color TV Standards (p. 63)

Magnetic Recording (p. 81) *M. Camras*

vol. 12, Oct. 1953

Flexible TV Studio Intercom System (p. 79) *R. D. Chipp and R. F. Bigwood*

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 Membership Directory.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Aspaas, S. J., Salesman, National Theatre Supply, 1961 South Vermont Ave., Los Angeles 7, Calif. (A)

Aufhauser, Fred E., Manufacturer, Projection Optics Co., Inc., Rochester, N.Y. (A)

Bass, Robert, Film Producer, Bass Films, Inc. **Mail:** 923 Fifth Ave., New York, N.Y. (M)

Berk, Milton, Chief Projectionist, Capitol Theatre. **Mail:** 492 Oakdene Ave., Ridgefield, N.J. (M)

Bower, Wilford W., Technical Representative, W. J. German, Inc., John St., Ft. Lee, N.J. (A)

Brewer, W. Lyle, Supervisor, Physical Standards and Services Section, Color Technology Division, Eastman Kodak Co. **Mail:** 275 Sagamore Dr., Rochester, N.Y. (A)

Brooks, William N., Executive Vice-President, In Charge of Production, McGeary-Smith Laboratory. **Mail:** 2K Northway, Greenbelt, Md. (A)

Brush, John M., Electronic Engineer, A. B. DuMont Laboratories, Inc. **Mail:** 35 Belmont Ave., Clifton, N.J. (M)

Burgess, George, Sound Supervisor, Alliance Film Studios, Ltd. **Mail:** Flat 6, 72 Notting Hill Gate, London, W. 11, England. (A)

Burns, Robert E., Technical Consultant, W. J. German, Inc. **Mail:** 2340 Linwood Ave., Fort Lee, N.J. (A)

Cameron, Donald F., Television Engineer, Storer Broadcasting Co., (WSPD-TV). **Mail:** 1619 Milburn Ave., Toledo 6, Ohio. (A)

Cedrone, Nicholas J., Mechanical Engineer, Artisan Metal Products, Inc., 73 Pond St., Waltham 54, Mass. (A)

Chambers, Maude L., Art Programs for Color TV. **Mail:** 1901 Jackson St., Amarillo, Tex. (M)

Chapman, Christopher M., Film Producer. **Mail:** 293 Roxborough St., East, Toronto, Ontario, Canada. (A)

Clark, Thomas C., Jr., Electrical Engineer, Hughes Aircraft Co. **Mail:** 5381 Village Green, Los Angeles 16, Calif. (M)

Cope, Gerald B., Mechanical Engineer, AFMTC, Technical Systems Laboratory, Patrick Air Force Base. **Mail:** 58 Vesta Circle, Melbourne, Fla. (M)

Dougherty, Joseph T., Salesman, Raw Stock Sales, E.I. du Pont de Nemours & Co., Inc., 248 W. 18 St., New York, N.Y. (M)

Elms, Charles D., Motion-Picture Producer. **Mail:** 163 Highland Ave., North Tarrytown, N.Y. (M)

Evenden, W. Lewis, Television Engineer, WMBR-TV. **Mail:** 22—10 Ave., North, Jacksonville Beach, Fla. (M)

Getze, Walter F., Television Engineer, KLAC-TV. **Mail:** 198 South Commonwealth Ave., Los Angeles, Calif. (M)

Gubbins, L. J., Sound Recording Engineer, Compania Shell de Venezuela Ltd., Apartados 809, Caracas, South America. (A)

Hanley, Francis Xavier, Broadcasting and Television Studio Engineer, Bremer Broadcasting Corp. **Mail:** 647 E. 14 St., New York. (M)

Hayes, John D., Optical Engineer, Bausch & Lomb Co., Rochester 2, N.Y. (M)

Hazard, S. J., Importer, A. Hazard Co. **Mail:** 7 Lexington Ave., New York 10, N.Y. (A)

Heinzman, Lewis C., Radio-Television Engineer, McClatchy Broadcasting Co. **Mail:** 1930 Seventh Ave., Sacramento, Calif. (A)

Huether, George F., Television Studio Technical Supervisor, U.S. Navy Special Devices Center. **Mail:** 95 Falmouth Pl., Albertson, Long Island, N.Y. (A)

Hughes, John F., Film Editor, Movietonews, Inc., 460 W. 54 St., New York, N.Y. (M)

Jacobs, George, Television Engineer, National Broadcasting Company. **Mail:** 1802 E. 21 St., Brooklyn 29, N.Y. (M)

Jansen, Paul W., Sales Manager, Minnesota Mining & Manufacturing Co., 900 Fauquier Ave., St. Paul, Minn. (M)

Jansky, C. M., Jr., Radio and Electronic Engineer, Jansky & Bailey, Inc., 1339 Wisconsin Ave., N.W., Washington, D.C. (M)

Kivell, Donald W., Head, Camera & Stage Branch, U.S. Naval Photographic Center. **Mail:** 120 East Hunting Towers, Alexandria, Va. (A)

Kooser, H. L., Director, Visual Instruction Service, Iowa State College, Ames, Iowa. (A)

Kyburz, L. C., Director of Physical Properties, Jefferson Amusement Co. **Mail:** 2685 Hazel St., Beaumont, Tex. (M)

Landry, Robert William, Chief, Training Film Unit, NSA Defense Dept. **Mail:** 25 Southdown Rd., Alexandria, Va. (A)

Lavin, Thomas, Motion-Picture Printer, Signal Corps Pictorial Center. **Mail:** 332—42 St., Brooklyn, N.Y. (A)

Lindgren, Emanuel O., Equipment Inspector, Arabian American Oil Co., Box 1011, Dhahran, Saudi Arabia. (A)

Lindow, Walter, Sound Engineer, General Theatre Supply Co., Ltd. **Mail:** Apt. 8, 31 South St., Halifax, Nova Scotia. (A)

Lohse, Karl-Heinz, Microscopist and Photographer, Marathon Corp., Menasha, Wis. (A)

Lomas, Stanley A., Advertising Vice-President, Director, TV Commercial Dept., Wm. Esty Co., 100 E. 42 St., New York, N.Y. (M)

MacAdam, David L., Research Physics, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y. (A)

Madery, Earl M., Sound Technician RCA Victor Division. **Mail:** 4847 Alonzo Ave., Encino, Calif. (A)

Markley, Charles W., Engineer, Pathe Laboratories, 6823 Santa Monica Blvd., Los Angeles, Calif. (A)

Midorikawa, Michio, Technical Supervisor, Daiei Motion Picture Co. **Mail:** 1262, Noborito-cho, Kawasaki-city, Kanagawa-ken, Japan. (M)

Miller, Albert Robert, Sensitometrist, Color Corporation of America, 2800 West Olive, Burbank, Calif. (A)

Miller, Franklin C., Engineer, Fairchild Aerial Surveys, Inc. **Mail:** 3635 Kalsman Dr., Los Angeles 6, Calif. (A)

Mills, Kenneth N., Motion-Picture Production Technician, U.S. Government. **Mail:** 2210 Emerson Ave., Apt. 5, Dayton 6, Ohio. (A)

Minter, Jerry B., Radio Engineer, Measurements Corp. **Mail:** Box #1, Boonton, N.J. (M)

Mitchell, Hubert R., Manufacturer, Hubert Mitchell Industries, Inc., Box 690, Hartselle, Ala. (M)

Nagel, George A., Plant Superintendent, Consolidated Film, Main St., Ft. Lee, N.J. (M)

Peque, Raymond, Motion-Picture Projectionist, Supervisor of Shipbuilding, U.S. Navy. **Mail:** 65 Liberty St., Lodi, N.J. (A)

Rauenbuhler, Robert L., Engineering Technician U.S.N.S.R.&D.F., Naval Supply Depot. **Mail:** 10 Nesbitt St., Jersey City, N.J. (A)

Reeves, James J., Television Engineer, Columbia Broadcasting System. **Mail:** 1515 Metropolitan Ave., Apt. 4B, New York 62, N.Y. (M)

Rejlek, Frank X., Assistant to Producer, Gene Lester Productions. **Mail:** 10702 Holman Ave., Los Angeles 24, Calif. (M)

Seibel, Martin, Operator of Film Service, M. Seibel Film Service, Box 625, Industrial Branch, Hillside, N.J. (A)

Sorem, Allan L., Research Physicist, Research Laboratories, Eastman Kodak Co., Kodak Park, Rochester, N.Y. (M)

Tourangeau, Raymond G., Sales Supervisor, Ansco, 247 East Ontario St., Chicago, Ill. (A)

Wilkie, James W., President, Continental Machines, Inc., Savage, Minn. (A)

Wright, Harry G., Mechanical Engineer, Television Projectors, RCA Victor Division, Dept. 587, Bldg. 10–3, Camden, N.J. (M)

CHANGES IN GRADE

Wells, Thomas H., (A) to (M)
Shamberg, Kurt D., (S) to (A)

DECEASED

Kral, Karel B., Director, Manager, Griffin Film Enterprises, Griffin Lodge, Betsham, North Gravesend, Kent, England. (M)

Employment Service

These notices are published for the service of the membership and the field. They are inserted or three months, at no charge to the member. The Society's address cannot be used for replies.

Position Wanted

Motion-Picture Television Technician: 10 yr intensive skill and know-how related to 16-35mm cinematography, animation, recording (optical, tape, disk), editing, laboratory processing practice (black-and-white, color); also kinescope recording techniques; self-reliant; inventive; relocate if required; write: CMC, Technical Associates, 60 East 42d St., New York 17, N.Y.

Positions Available

Wanted: Sound Engineer for New York film production studio, operation and maintenance on optical and magnetic sound equipment; electronics background essential. Send résumé to R. Sherman, 858 West End Ave., New York, N.Y.

Technical Photographer, age 27 to 38, for senior position with large California industrial research organization. Should be conversant with contemporary techniques for recording data; acquainted with microscopy, graphic arts and color processes. Job involves application of photographic techniques as experimental tool in research projects. Administrative experience helpful. Excellent career opportunity for an ingenious and inventive person. Retirement pension and other benefit plans. Application held in strict confidence. Write giving personal data, education and experience to Henry Helbig and Associates, Placement Consultants, Examiner Bldg., 3d and Market Sts., San Francisco 3, Calif.

Sound Engineer: Complete responsibility for sound control, including printing, processing, maintenance of standards, etc. Tri Art Color Corp., 245 West 55th St., New York 19, N.Y.

Motion-Picture Supervisor, GS-8: Duties as Chief of Motion Picture Section to include all phases of aeromedical research cinematography. Experience in planning, directing, lighting, color control, recording in single or double-system sound. Laboratory work requires experience with sensitometric control equipment, contact printers, automatic processors, Moviola, sound synchronization equipment, titlers, etc. For detailed information write: Photography Officer, USAF School of Aviation Medicine, Randolph Field, Texas.

Motion-Picture Sound Transmission Installer and Repairer, for the Signal Corps Pictorial Center, Long Island City, N.Y.—one at $2.59/hr; one at $2.29/hr (40-hr week). Applicants for $2.29/hr position must have had 4½ yr progressively responsible experience in the construction, installation and maintenance of electronic equipment, of which at least 1½ yr must have been in the specialized field of motion-picture film, disk or magnetic sound recording or reproducing equipment. Applicants for $2.59/hr position must have had at least 5 yr responsible experience in the design, development and installation of electronic equipment, of which at least 2 yr must have been in the specialized field of motion-picture film, disk or magnetic sound recording or reproducing equipment. Must be familiar with filter design and transmission testing, involving the use of a wide variety of testing and measuring devices. Each year of study successfully completed in a residence school above high school level in electrical, electronic or radio engineering, may be substituted for the general, but not the specialized experience indicated above, at the rate of one scholastic year for each 9 mo. of experience. All applicants must be familiar with Western Electric and RCA systems. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or bring completed form to Civilian Personnel Division, Signal Corps Pictorial Center, 35–11 35th Ave., Long Island City, N. Y.

New Membership Directory

At the first of this month, dues bills went to members in the United States, with a return envelope bearing a clipping of their 1952 Membership Directory listing. Earlier, the same was sent to members outside the United States. The returned and corrected clippings will be the basis for a new directory, scheduled to be Part II of the April *Journal.*

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal.*

Papers Presented at the New York Convention, October 5–9

MONDAY NOON—Get-Together Luncheon

MONDAY AFTERNOON—Basic Principles—Stereophony and Stereoscopy

W. B. Snow, Consultant in Acoustics, Los Angeles, Calif., "Basic Principles of Stereophonic Sound."

D. L. MacAdam, Eastman Kodak Co., Rochester, N.Y., "Stereoscopic Perceptions of Size, Shape, Distance and Direction."

TUESDAY MORNING (Concurrent Sessions)
————Equipment for Stereophonic Sound Reproduction

C. C. Davis and H. A. Manley, Westrex Corp., Hollywood, Calif., "An Auxiliary Multitrack Magnetic Sound Reproducer."

J. D. Phyfe, RCA Victor Division, Camden, N.J., and C. E. Hittle, RCA Victor Division, Hollywood, Calif., "A Film-Pulled, Theater-Type, Magnetic Sound Reproducer for Use With Multitrack Films."

S. W. Athey, Willy Borberg and R. A. White, General Precision Laboratory, Inc., Pleasantville, N.Y., "A Four-Track, Magnetic Theater Sound Reproducer for Composite Films."

J. K. Hilliard (Moderator), Altec Lansing Corp., Los Angeles, Calif., Panel Discussion on "Equipment for Stereophonic Sound Reproduction."

————High-Speed Photography Session

John H. Waddell, Wollensak Optical Co., Rochester, N.Y., "Critique of High-Speed Photography Demonstration Films."

J. S. Watson, Jr., S. A. Weinberg and G. H. Ramsey, University of Rochester School of Medicine and Dentistry, Rochester, N.Y., "Stereoscopic X-Ray Motion Pictures."

H. M. Ferree, General Electric Co., Nela Park, Cleveland, Ohio, "Glow-Lamps in High-Speed Photography and Related Applications."

Peter Carey, K. C. Halliday and F. B. Terry, Eclipse-Pioneer, Division Bendix Aviation Corp., Teterboro, N.J., "High-Speed Photography of Flame Initiation Phenomena."

Isaac S. Goodman, Westinghouse Electric Corp., Lamp Division, Bloomfield, N.J., "Application of High-Speed Motion-Picture Photography to Quality and Processes Analysis in the Lamp Industry."

R. W. Nottorf and W. H. Vinton, E. I. du Pont de Nemours & Co., Inc., Photo Products Division, New York, "New Reversal Film Suitable for Normal or Rapid Processing."

John H. Waddell (Moderator), Wollensak Optical Co., Rochester, N.Y., "Open Forum on High-Speed Photography."

TUESDAY AFTERNOON—Laboratory Practices Session

A. A. Rasch and J. I. Crabtree, Kodak Research Laboratories, Rochester, N.Y., "Development of Motion-Picture Positive Film by Vanadous Ion."

Samuel R. Goldwasser, Signal Corps Pictorial Center, Long Island City, N.Y., "A Mathematical Approach to Replenishment Techniques."

A. H. Vachon, National Film Board of Canada, Ottawa, Ontario, Canada, "Stainless-Steel Developing-Machine Rollers."

Walter R. J. Brown, Eastman Kodak Co., Rochester, N.Y., "A Rapid Scanning Microdensitometer."

TUESDAY EVENING—Armed Forces—Foreign-Language Conversions

Thomas Baird, United Nations Headquarters, New York, "International Film Audience."

Otto Rauhut, Condor Films, Inc., St. Louis, Mo., "Direct-Positive Variable-Density Recording Utilizing Supersonic Bias With Galvanometer-Type Light Modulator."

Max G. Kosarin, Signal Corps Pictorial Center, Long Island City, N.Y., "Preparation of Foreign Language Versions of U.S. Army Films."

George Lewin, Signal Corps Pictorial Center, Long Island City, N.Y., "Magnetically Striped Loops for Lip-Synchronizing Production."

J. C. Greenfield, U.S. Naval Photographic Center, Anacostia, D.C., "Language Conversion, Other Applications; Using a Special 16mm Magnetic Projector-Duplicator."

E. W. D'Arcy, DeVry Corp., Chicago, Ill., "A Film-Exchange Foreign-Language Conversion Equipment."

WEDNESDAY MORNING—Television Film Reproduction, Color and Monochrome

R. G. Neuhauser, RCA Tube Department, Lancaster, Pa., "Vidicon Camera Tube for Film Pickup."

H. N. Kozanowski, RCA Victor Division, Camden, N.J., "Vidicon Film-Reproduction Cameras."

Warren R. Isom, RCA Victor Division, Camden, N.J., "A Fast-Cycling Intermittent for 16mm Film."

Raymond W. Wengel, Camera Works, Eastman Kodak Co., Rochester, N.Y., "A Pneumatic Pulldown 16mm Projector."

Ernest H. Traub, Philco Corp., Philadelphia, Pa., "New 35mm Television Film Scanner."

V. Graziano and Kurt Schlesinger, Motorola, Inc., Chicago, Ill., "A Continuous All-Electronic Scanner for 16mm Color Film."

WEDNESDAY AFTERNOON—Television—Theater, Recording, Lighting

F. A. Cowan, American Telephone and Telegraph Co., New York, "Networks for Theater Television."

D. J. Parker, S. W. Johnson and L. T. Sachtleben, RCA Victor Division, Camden, N.J., "Apparatus for Aperture-Response Testing of Large Schmidt-Type Projection Optical Systems."

R. M. Fraser, National Broadcasting Co., New York, "A New 35mm Single-Film-System Kinescope Recording Camera."

William R. Ahern, National Broadcasting Co., New York, "Television Lighting Routines."

THURSDAY AFTERNOON—Color and Black-and-White Reproduction

H. H. Schroeder and A. F. Turner, Bausch & Lomb Optical Co., Rochester, N.Y., "Primary Color Filters With Interference Films."

Ralph M. Evans and W. Lyle Brewer, Eastman Kodak Co., Rochester, N.Y., "The First and Second Black Conditions."

C. R. Anderson, C. E. Osborne, F. A. Richey and W. L. Swift, Eastman Kodak Co., Rochester, N.Y., "Sensitometry of the Color Internegative Process."

A. L. Sorem, Eastman Kodak Co., Rochester, N.Y., "The Effect of Camera Exposure on the Tone Reproduction Quality of Motion Pictures."

THURSDAY EVENING—Three-Dimensional Film Equipment and Practices

Chester E. Beachell, National Film Board of Canada, Ottawa, Canada, "A 35mm Stereo Cine Camera."

R. Clark Jones and W. A. Shurcliff, Polaroid Corp., Cambridge, Mass., "Equipment to Measure and Control Synchronization Errors in 3-D Projection."

W. A. Shurcliff, Polaroid Corp., Cambridge, Mass., "Screens for 3-D and Their Effect on Polarization."

L. W. Chubb, D. S. Grey, E. R. Blout and E. H. Land, Polaroid Corp., Cambridge, Mass., "Properties of Polarizers for Filters and Viewers for 3-D Motion Pictures."

A. J. Cardile and J. J. Hoehn, RCA Victor Division, Camden, N.J., "New Portable 16mm Arc Projector Adapted for 3-D Projection."

Raphael G. Wolff, Wolff Studios, Hollywood, Calif., "Three-Dimensional Films for Business and Industry."

FRIDAY MORNING—Recent History of New Techniques—Wide-Screen Methods

Ben Schlanger (Committee Chairman), Theater Consultant, New York, "Theater Screen Survey."

Ralph H. Heacock, RCA Victor Division, Camden, N.J., "Practical Application of New Motion-Picture Techniques Introduced in Theaters During the Past Year."

Fred Waller, Cinerama, Inc., New York, "The Cinerama Process."

John D. Hayes, Bausch & Lomb Optical Co., Rochester, N.Y., "CinemaScope Optics."

Edgar Gretener, Dr. Edgar Gretener, A.G., Zurich, Switzerland, "An Improved Carbon-Arc Light Source for Three-Dimensional and Wide-Screen Projection."

C. E. Greider, National Carbon Co., Cleveland, Ohio, "Performance of High-Intensity Carbons in the Blown Arc."

FRIDAY AFTERNOON—General Session

M. A. Hankins and Peter Mole, Mole-Richardson Co., Hollywood, Calif., "Recent Development of a Compact High-Output Engine-Generator Set for Lighting Motion-Picture and Television Locations."

R. J. Youngquist and W. W. Wetzel, Minnesota Mining & Mfg. Co., St. Paul, Minn., "Ferrite-Core Heads for Magnetic Recording."

J. K. Hilliard (Committee Chairman), Altec Lansing Corp., Los Angeles, Calif., "Sound Committee Report."

J. G. Frayne (Moderator), Westrex Corp., Hollywood, Calif., Panel Discussion on "Magnetic Head Wear."

Meetings

American Institute of Electrical Engineers, Winter General Meeting, Jan. 18–22, 1954, New York

National Electrical Manufacturers Assn., Mar. 8–11, 1954, Edgewater Beach Hotel, Chicago, Ill.

Radio Engineering Show and I.R.E. National Convention, Mar. 22–25, 1954, Hotel Waldorf Astoria, New York

Optical Society of America, Mar. 25–27, 1954, New York

The Calvin Eighth Annual Workshop, Apr. 12–14, 1954, The Calvin Co., Kansas City, Mo.

Society of Motion Picture and Television Engineers, Central Section, Spring Meeting, Apr. 15, 1954, The Calvin Co. Sound Stage, Kansas City, Mo.

75th Semiannual Convention of the SMPTE, May 3–7, 1954, Hotel Statler, Washington

American Institute of Electrical Engineers, Summer General Meeting, June 21–25, 1954, Los Angeles, Calif.

Acoustical Society of America, June 22–26, 1954, Hotel Statler, New York

Illuminating Engineering Society, National Technical Conference, Sept. 12–16, 1954, Chalfonte-Haddon Hall, Atlantic City, N.J.

Photographic Society of America, Annual Meeting, Oct. 5–9, 1954, Drake Hotel, Chicago, Ill.

American Institute of Electrical Engineers, Fall General Meeting, Oct. 11–15, 1954, Chicago, Ill.

76th Semiannual Convention of the SMPTE, Oct. 18–22, 1954 (next year), Ambassador Hotel, Los Angeles

77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955, Drake Hotel, Chicago

78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955, Lake Placid Club, Essex County, N.Y.

INDEX TO SUBJECTS

July — December 1953 • Volume 61

LIGHTING (see also ARCS and HIGH-SPEED PHOTOGRAPHY)

General

Projection

Studio

NEW PRODUCTS

OBITUARIES

OPTICS

PHOTOMETRY (see also LIGHTING, OPTICS and SCREEN BRIGHTNESS)

PROJECTION

16mm and 8mm

35mm

SOUND REPRODUCTION

General

Loudspeakers

STANDARDS and RECOMMENDATIONS:

See the listing on p. 778 or the specific subject heading.

STEREOSCOPY

TELEVISION (see also LIGHTING and THEATER TELEVISION)

General

Films

Picture Quality

THEATER

Lighting

American Standards — by numbers

(See "Status of Motion-Picture Standards," pp. 79–82 of the July *Journal*, for a tabulation of all standards in force, proposed and withdrawn.)

INDEX TO AUTHORS

July — December 1953 • Volume 61